Volume 60 Number 718
October 1987

Acc.
22.8.88

THE BRITISH JOURNAL OF RADIOLOGY

14

CUK-H06088-14-P25848

X-ray diagnosis
Radiotherapy
Nuclear medicine
Ultrasound
Nuclear magnetic resonance
Radiological physics
Radiobiology
Oncology
Hyperthermia
Radiation protection

UNIVERSITY COLLEGE OF
LIBRARY
C. U.

Published b
Th itish Institute of Radiolog

The British Journal of Radiology

Founded 1896

The Editorial Committee consists of:

The Editors:

J. T. Patton, F.R.C.P., F.R.C.R. N. J. McNally, B.SC., M.SC., PH.D.

The Deputy Editors:

D. G. Shaw, F.R.C.P., F.R.C.R. C. K. Bomford, B.SC., M.PHIL., F.INST.P.

and

The Associate Editors:

J. E. Adams, M.B., B.S., M.R.C.P., F.R.C.R.
P. R. Blake, M.B., B.S., B.SC., F.R.C.R.
J. A. Bullimore, M.B., B.S., M.R.C.S., L.R.C.P., D.M.R.T., F.R.C.R.
P. Dawson, B.SC., PH.D., M.B.B.S., M.R.C.P., M.INST.P., F.R.C.R.
S. Dische, M.D., F.R.C.R.
F. A. Duck, PH.D., M.I.E.E.E.
A. H. Freeman, M.B., B.S., F.R.C.R.
R. M. Harrison, B.SC., M.SC., PH.D., M.INST.P.
J.W. Hopewell, B.SC., PH.D.
W. D. Jeans, M.B., B.S., F.R.C.R.
C. H. Jones, B.SC., PH.D., F.INST.P.
D. M. King, M.B.B.S., F.R.C.R., D.M.R.D.
H. W. C. Loose, D.M.R.D., F.R.C.R.
D. W. Pilling, M.B., CH.B., D.C.H., D.M.R.D., F.R.C.R.
M. J. Raphael, M.A., M.D., F.R.C.P., F.R.C.R., D.M.R.D.
J. R. K. Savage, D.SC.
R. A. Shields, PH.D.
A. R. Valentine, M.B., B.S., M.R.C.S., L.R.C.P., F.R.C.R., D.M.R.D.
G. H. Whitehouse, M.B., B.S., F.R.C.P., F.R.C.R., D.M.R.D.
A. G. Wilson, F.R.C.P., F.R.C.R.
E. P. Wraight, M.B., B.CHIR., PH.D., D.M.R.T.

The Associate Editors Overseas are:

P. Armstrong, M.B., B.S., F.R.C.R., D.M.R.D. (North America)
H. K. Baddeley, M.B., B.S., D.M.R.D., F.R.C.R., M.R.A.C.R. (Australasia)
S. G. A. Chenery, PH.D., F.C.C.P.M. (North America)
B. J. Cremin, F.R.C.R., F.R.A.C.R. (South Africa)
R. Fox, D.PHIL. (Australia)
M. Takahashi, M.D. (Japan)
D. M. Taylor, D.SC., C.CHEM., F.R.S.C. (Continental Europe)

Managing Editor: Lynn Whitfield, B.SC.

Communications should be addressed to the Editors in accordance with the Instructions to Authors which are published in the January issue of the Journal in each year and copies of which may be obtained on application to the Managing Editor.

Advertisements: Communications should be addressed to Advertising Dept., The British Journal of Radiology, 36 Portland Place, London W1N 4AT (01-631 1168).

Subscriptions: All communications should be sent to The British Institute of Radiology, 36 Portland Place, London W1N 4AT, England. Notification of change of address should include an old mailing label and the new address. Claims for missing copies can only be allowed if received within four months of normal delivery date.

Annual Subscription: £90 per annum, payable in advance (USA, $159/India, £94). Single copies: £10.00 (available from UK office).

USA, Canada, Central and South America, Mexico, West Indies: Orders to British Journal of Radiology, P.O. Box #2513, Birmingham, Alabama 35201, USA.

Air-speeded delivery. Second class postage paid at Rahway, N. J. Postmaster: send address corrections to The British Journal of Radiology, c/o Mercury Airfreight International Ltd Inc., 10B Englehard Avenue, Avenel, NJ 07001. British Journal of Radiology (ISSN 0007-1285), monthly.

India: Orders to Universal Subscription Agency Pvt. Ltd., 101–102 Comm. Centre, PB No. 8, Malviya, Nagar Extn., Saket, New Delhi 110017, India (air-speeded delivery).

The British Institute of Radiology

Incorporated by Royal Charter
Patron: Her Majesty The Queen

P25848

Founded 1897

36 PORTLAND PLACE, LONDON W1N 4AT

Telephone: 01-580 4085 and 01-580 4189. Cable Address: "Britology, London W.1."

President: G. Mountford, M.C.A.M., D.I.P.M., M.B.I.M., D.C.R.

Hon. Secretaries:
M. Gowland, M.B., CH.B., F.R.C.R., M.R.C.P. (HON.)
M. J. Harvey, T.D.C.R., D.M.S.

General Secretary: Susan M. Johnstone, B.A.

The British Institute of Radiology is an association of persons interested in Radiology and allied subjects. Meetings are held monthly from October until May. Particulars of membership and other information may be obtained on application to the General Secretary at the Institute.

Vol. 60

Schering experience in contrast media ws in the carefully selected range of 's and presentations in which Urografin ') is supplied. In ampoules or bottles, Urografin 150 is available in the volumes ded for a wide range of radiographic estigations – so that the administration ocedure is not interrupted by the straction of changing bottles. The 500ml ize, for example, is specially produced for cystography and videocystometry.

Urografin has been proved by thirty years of experience to give acceptable tolerance, first-class contrast and a low incidence of side-effects at a very modest cost.

In contrast media, experience tells.

Urografin 150

Schering. Clearly a first-class choice.

CRIBING INFORMATION UROGRAFIN 150 – **Presentation:** An intravenous injection of meglumine diatrizoate 26.1% w/v and sodium diatrizoate 3.9% w/v containing 146mg iodine/ml. s: X-ray contrast medium for the delineation of the vascular and renal systems. **Dosage and Administration:** Drip-infusion urography 2-4ml/kg body weight up to 250ml, retrograde rography 5-10ml, Cystography up to 500ml. **Contra-indications:** Proven or suspected hypersensitivity to iodine-containing contrast media; manifest thyrotoxicosis; decompensated cardiac nsufficiency; hysterosalpingography during pregnancy; acute pelvic inflammation. **Warnings, etc:** Carefully consider need for examination if there is: Severe impairment of hepatic or renal tion; cardiac or circulatory insufficiency; cerebral arteriosclerosis; cerebral spasmodic conditions; epilepsy; juvenile-onset or long-standing diabetes; pulmonary emphysema; poor general th; hyperthyroidism; multiple myeloma; a history of allergy. Since safety during pregnancy is not certain, X-ray examinations should be done only if essential. Allergic patients may be persensitive. Particular caution in allergic persons who have tolerated a contrast medium without complication; they may have become sensitized. Contrast media and anti-allergic agents must not be mixed. In patients with multiple myeloma, juvenile-onset or long-standing diabetes, polyuria, oliguria, gout or marasmus, and in infants and young children, fluids should not be ricted. Disturbances of water and electrolytes must first be corrected. Premedication with an alpha-blocker is recommended in patients with phaeochromocytoma. Administer Urografin 150 to recumbent patients, and closely observe for at least 15 minutes. If not already on the X-ray table, those with labile circulations should be brought to the table sitting or lying. Urografin 150 ces the capacity of the thyroid to take up iodine for a few days, and sometimes up to 6 weeks. Mild symptoms, such as heat and nausea, disappear rapidly when the injection is slowed down terrupted. Transient pain may occur, in particular during peripheral vascular examinations. Extravasations rarely cause serious tissue reactions. If marked side-effects or suspected allergic actions occur during injection, and do not disappear, or even worsen, when it is interrupted stop the investigation. Even minor symptoms such as itching, sneezing, violent yawns, tickling in throat, hoarseness or coughing may be early signs of a severe reaction. [illegible] or life-threatening side-effects include hypotensive collapse, circulatory failure, ventricular ilation, cardiac arrest, pulmonary oedema, anaphylactic shock or other alle [illegible] s, and co [illegible] er cerebral symptoms. **Basic NHS price:** 10 x 10ml: **£11.25;** 10 x 20ml: 75; 1 x 250ml: **£9.21;** 1 x 500ml: **£18.00.**

uct Licence no.: 0053/5041. Product Licence holder: Schering [illegible] Schering H [illegible] The Brow, Burgess Hill, West Sussex RH15 9NE. Telephone: 04446 6011.

TAKE THE HIGH ROAD
TO SCOTLAND

RADIOLOGY '88

23-25 May 1988 Glasgow

Britain's Open Forum
for all concerned with medical radiology
both diagnostic and therapeutic

STAR SPEAKERS
PROFFERED PAPERS
EXCITING SOCIAL PROGRAMME
MAJOR SCIENTIFIC POSTER EXHIBITION

MED **X** RAY

Britain's biggest radiological technical exhibition will span Radiology '88
and the annual conference of the College of Radiographers

RADIOLOGY '88
GLASGOW

Further information from
Conference Office
THE BRITISH INSTITUTE OF RADIOLOGY
36 Portland Place
London W1N 4AT
Telephone: 01-580 4085

RADIOLOGY '88
GLASGOW

elscint

The Image You Can Rely On

Magnetic Resonance Imaging

Computed Tomography

Nuclear Medicine

Ultrasound

Mammography

ELSCINT (G.B.) LTD
Tower Road, Berinsfield, Oxfordshire OX9 8LW
Tel: Oxford (0865) 340900
Fax: Oxford (0865) 341050 Telex: 83341

SIEMENS

SOMATOM DR from Siemens – uture applications demand eading-edge technology today

In choosing a whole-body computed tomography scanner, you don't just want the best system available today. You also want a commitment that assures you of the best system tomorrow.
That's why you should consider all of the factors involved and demand superior image quality, fast patient throughput, proven reliability, flexible and easy operation, and a system engineered for the future. Why should you have to settle for less?

Make sure that the scanner you choose has these capabilities and is supported by a company committed to keeping you up with the state-of-the-art and with a tightly woven service network that can assure you of maximum utilization for your system.
In the final analysis, you'll find that the SOMATOM® DR from Siemens is the CT scanner for you and your hospital. Here are just a few of its advantages:

SCINTILLARC 700 – The detector array that provides you with superior resolution.

BSP 11 – The fast image processor that gives you the images you need, when you need them, and how you want to see them.

OPTI 155 CT – The CT x-ray tube that ensures fast patient throughput.

MICROMATIC CT — The only CT generator offering space saving high-frequency technology.

Comprehensive and Comprehensible Software – Constant software advancement and frequent upgrades keep you at the forefront of CT medical applications.

For more information contact
Siemens Limited
Medical Division
Siemens House
Windmill Road
Sunbury-on-Thames
Middlesex TW16 7HS
Tel: (0932) 785691
Telex: 8951091

Setting Standards in Diagnostic Imaging… Siemens

This book has met with the international success it deserves!

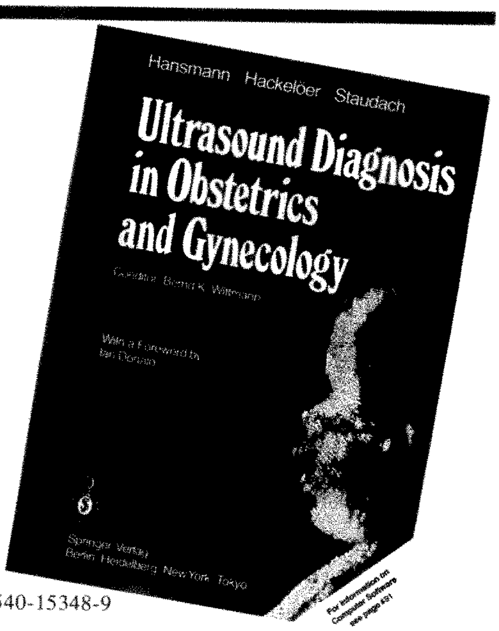
Is it already a part of your library? We strongly recommend it!

M. Hansmann, Bonn; **B.-J. Hackelöer,** Marburg;
A. Staudach, Salzburg

Ultrasound Diagnosis in Obstetrics and Gynecology

Translated from the German by T. C. Telger
Coeditor of the English edition: **B. K. Wittmann,** Vancouver
With a Foreword by **I. Donald,** Glasgow

1986. 589 figures. XVIII, 495 pages. Hard cover DM 280,–. ISBN 3-540-15348-9
German edition also available


Hansmann Hackelöer Staudach
Ultrasound Diagnosis in Obstetrics and Gynecology
Springer-Verlag
For information on Computer Software see page 431

Contents: Physics and Instrumentation in Diagnostic Ultrasound. – Safety of Diagnostic Ultrasound. – Examination of the Female Pelvis. – Pregnancy (First Trimester). – Multiple Pregnancy. – Amniocentesis. – Normal Fetal Anatomy in the Second and Third Trimester. – Fetal Malformations. – Rhesus Incompatibility and Nonimmunologic Hydrops Fetalis. – Phenotype and Rare Syndromes. – The Placenta. – The Cervix. – Postpartum Ultrasound. – Ultrasound Screening. – Sonographic Aspects of the Menstrual Cycle. – Pathology of the Genital Tract. – Intrauterine Contaceptive Devices. – Diagnosis of Breast Disease. – Appendix. – Subject Index. – A Simple Reporting Program for Obstetrical Ultrasound.

From the reviews:

"...The quality and extensiveness of the illustrations alone warrant purchasing this book. Normal development is discussed exhaustively with excellent demonstration of normal fetal anatomy for the novice. Fetal malformations are particularly well illustrated with the book serving as a library of abnormal cases.

For one who appreciates data well illustrated and usefully presented in table format and extensive graphs to document fetal growth as I do, there is material in this book that is not easily found in any other source. The percentile growth curves shown in the appendix are a valuable reference source...

I strongly recommend this as an outstanding textbook."

Harvey L. Neiman
American Journal of Roentgenology

"The main authors are well known in the international ultrasound community and have combined their individual experience and skill to provide a comprehensive treatise. The text is liberally illustrated with up to date scans and extensively referenced, citing numerous European publications as well as giving due credit to American ones when appropriate.
...undoubtedly the most up to date, comprehensive, readable, and valuable book on obstetric and gynaecological ultrasound."

British Medical Journal

"...the sonograms, drawings, and photographs are of the highest order in both the quality of material and quality of reproduction (in part due to the choice of matte rather than glossy paper). The illustrations are closely located to the related text. It is obvious that great care was taken in their organization and reproduction. The combination of paper and typeface makes reading the text easy on the eyes, even for prolonged periods. This book is appropriate for the beginning as well as the advanced sonographer (radiologist, obstetriciar... or perinatologist). Its very readable style, due in no small part to the translator, leads one easily from the basic concepts to the complex without any turmoil. Overall, I have no hesitation in recommending this text."

Joseph Blankier
Radiology

Springer-Verlag
Berlin Heidelberg New York London Paris Tokyo
Heidelberger Platz 3, D-1000 Berlin 33 · 175 Fifth Ave., New York, NY 10010, USA
28, Lurke Street, Bedford MK40 3HU, England · 26, rue des Carmes, F-75005 Paris
37-3, Hongo 3-chome, Bunkyo-ku, Tokyo 113, Japan

3999/4/1

Springer

RIKEN

From low energy X-ray to high energy Gamma-ray

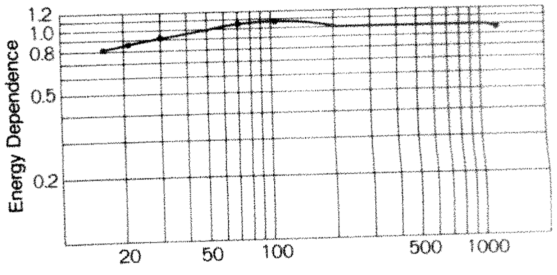
DIGITAL ALARM DOSIMETER REMSEVEN

AGENT WANTED

FEATURES

- The lowest price: ½-⅓ price of the others.
- Available to measure from low energy X-ray to high energy Gamma-ray. (10Kev-3Mev)
- As ion chamber method is applied, this exceeds in energy dependence.
- Not damaged by high dose.
- External output (0-1 VDC) is provided and connectable with recorder.
- Small size: 70 width x 100 height x 28 depth/mm.
- Light weight: approx. 170g.
- Standard range: 0-100mR.
- Display: digital display. (1mR/digit).
- Alarm: adjustable 5 stsps. (65dB at 20cm).
- Power source: dry cells, recharger contained in the body.

Energy dependence

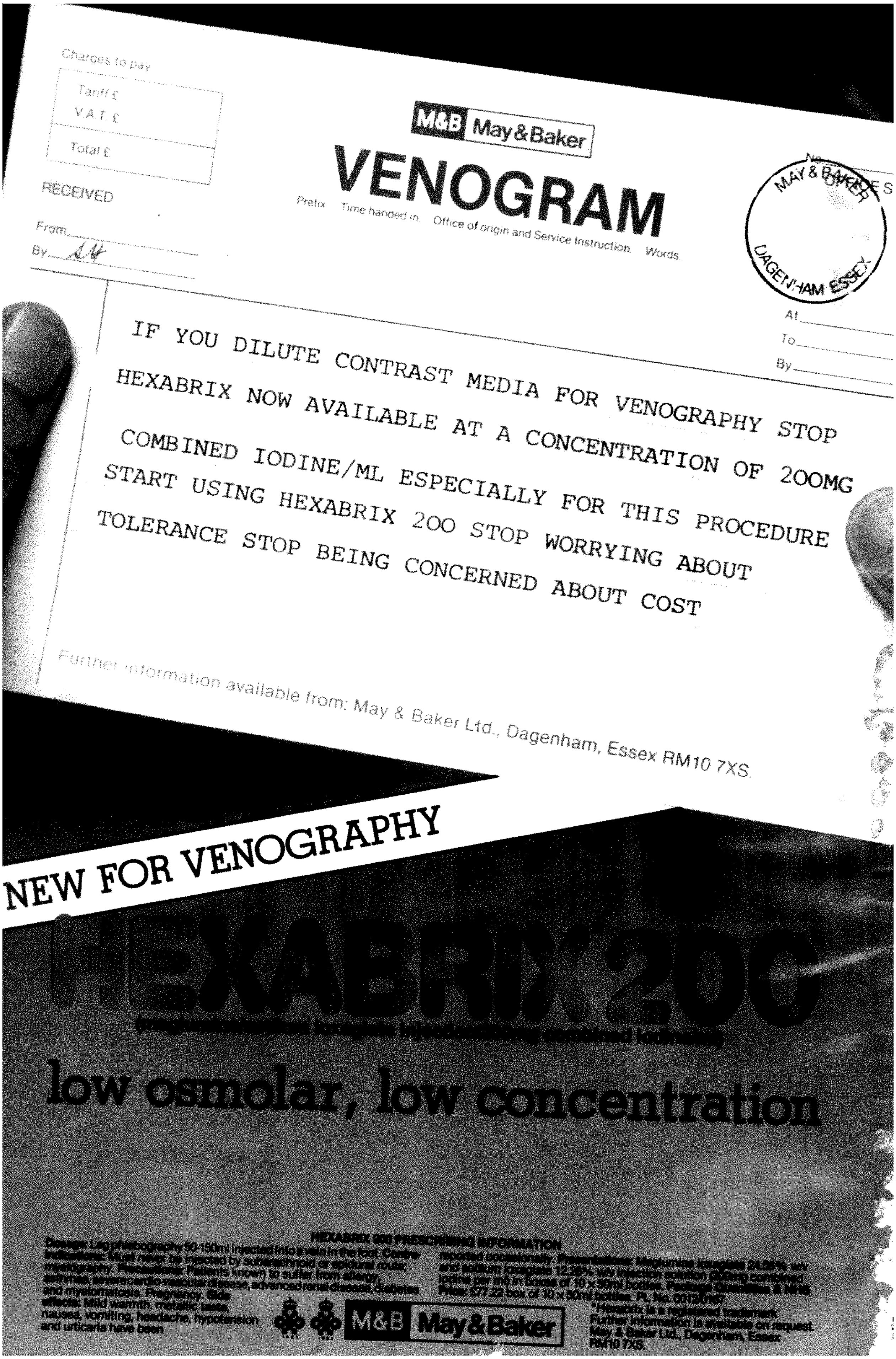


X & Gamma rays effective energy (Kev)

★ **Distributed by:**

NIPPON DENKI SHOJI CORP.
2-3-18 Ishizaka Build.
Nishikanda Chiyodaku
Tokyo 101 JAPAN.
Tel: (03)-265-1051
Fax: (03)-265-1053

Pocket dosimeters. Radiation monitoring systems.
Radiation survey meters. "HITACHI" X-ray tubes.



Charges to pay
Tariff £
V.A.T. £
Total £

RECEIVED
From
By AH

M&B May&Baker

VENOGRAM

Prefix Time handed in Office of origin and Service Instruction Words

No.
MAY & BAKER
DAGENHAM ESSEX

At
To
By

IF YOU DILUTE CONTRAST MEDIA FOR VENOGRAPHY STOP HEXABRIX NOW AVAILABLE AT A CONCENTRATION OF 200MG COMBINED IODINE/ML ESPECIALLY FOR THIS PROCEDURE START USING HEXABRIX 200 STOP WORRYING ABOUT TOLERANCE STOP BEING CONCERNED ABOUT COST

Further information available from: May & Baker Ltd., Dagenham, Essex RM10 7XS.

NEW FOR VENOGRAPHY

HEXABRIX* 200

([illegible] ioxaglate injection [illegible] combined iodine/ml)

low osmolar, low concentration

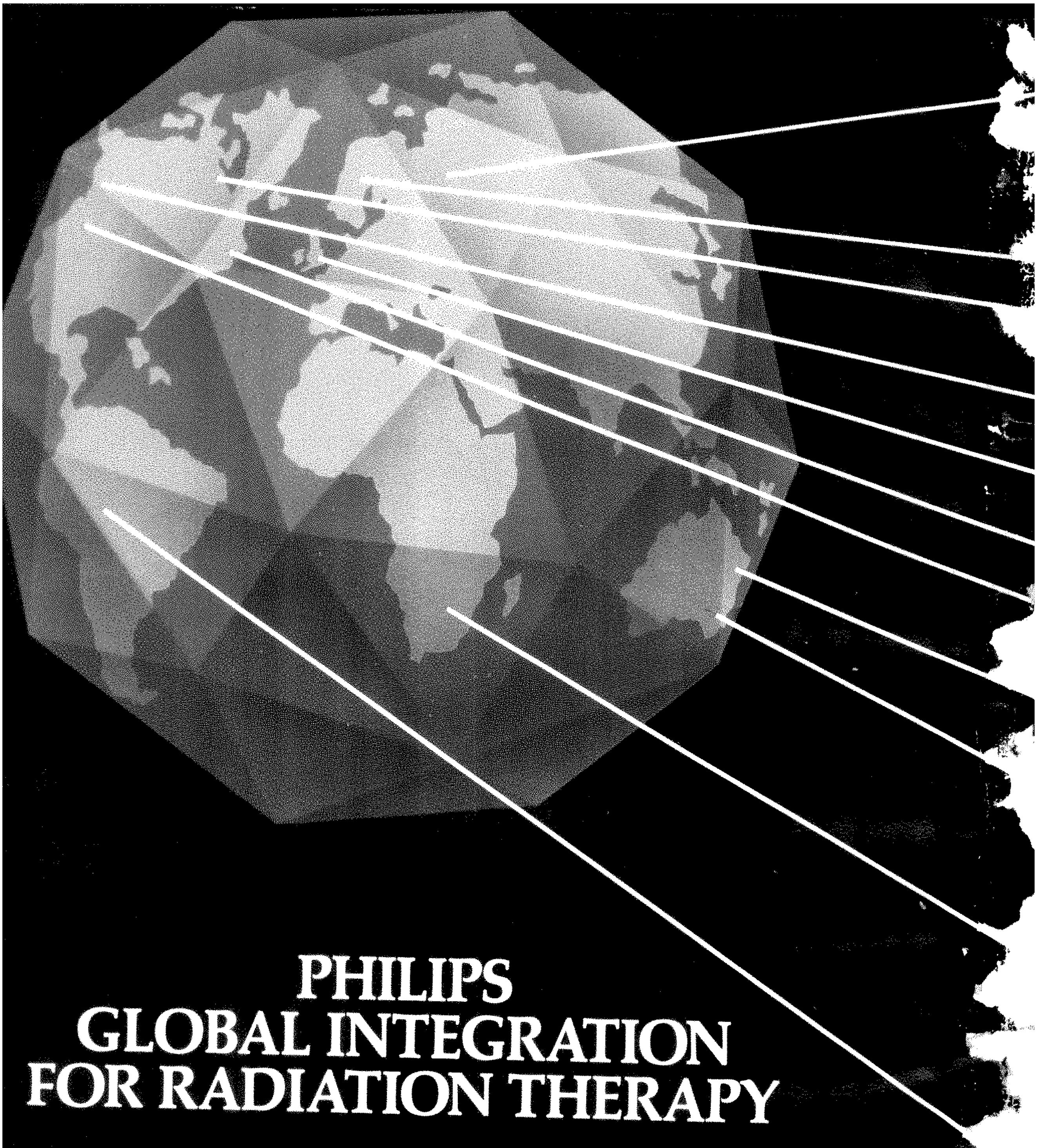
HEXABRIX 200 PRESCRIBING INFORMATION

Dosage: Leg phlebography 50-150ml injected into a vein in the foot. **Contra-indications:** Must never be injected by subarachnoid or epidural route; myelography. **Precautions:** Patients known to suffer from allergy, asthma, severe cardio-vascular disease, advanced renal disease, diabetes and myelomatosis. Pregnancy. **Side effects:** Mild warmth, metallic taste, nausea, vomiting, headache, hypotension and urticaria have been reported occasionally. **Presentations:** Meglumine ioxaglate 24.56% w/v and sodium ioxaglate 12.28% w/v injection solution (200mg combined iodine per ml) in boxes of 10 x 50ml bottles. **Package Quantities & NHS Price:** £77.22 box of 10 x 50ml bottles. PL No. 0012/0167.

M&B May&Baker

*Hexabrix is a registered trademark.
Further information is available on request.
May & Baker Ltd., Dagenham, Essex
RM10 7XS.

ACHIEVEMENT OF EXCELLENCE

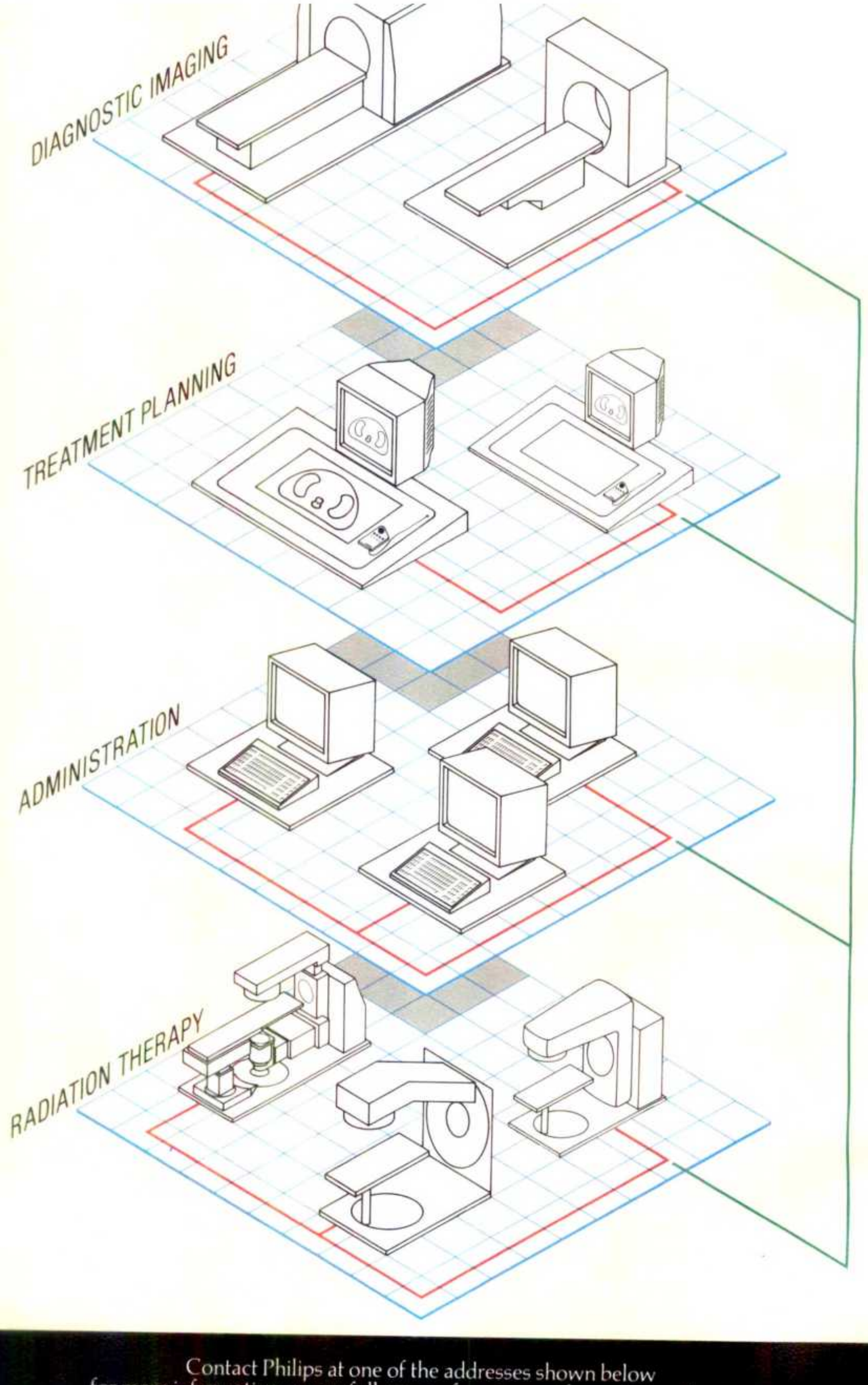


PHILIPS
GLOBAL INTEGRATION
FOR RADIATION THERAPY

- ❋ Computer aided patient positioning
- ❋ Automatic data transfer
- ❋ High patient throughput
- ❋ Integrated range of compatible systems
- ❋ Networking for optimal data management
- ❋ Exceptional treatment versatility
- ❋ Remote service facility
- ❋ Minimum down time

IPS

PHILIPS
Me
Sy



Contact Philips at one of the addresses shown below
for more information on our full range of equipment for radiation therapy.

Philips Medical Systems, Kelvin House, 63/67 Glenthorne Road, Hammersmith, London W6 0LJ.
Philips Radiotherapy Division, Manor Royal, Crawley, Sussex RH10 2PZ,
Divisions of Philips Electronic & Associated Industries Ltd.

Philips Medical Systems Inc, 710 Bridgeport Avenue, Shelton, Connecticut 06484, United States of America.
N.V. Philips, Medical Systems Division, Eindhoven, The Netherlands.

HILIPS

PHILIPS **Medical Systems**

RADIATION ONCOLOGIST

Immediate opening for a Board-certified Radiation Oncologist to join four staff radiation oncologists in a 700+ bed, hospital-based medical school program. Equipment includes a GE Target Treatment Planning system, the Memorial Dose Distribution System supported by a VAX 750 computer, Varian 4/100, 6/100, 2500 linear accelerators, a Varian Ximatron Simulator, CIS remote after loading computerized brachytherapy systems, a BSD 500 Interstitial Hyperthermia System, and a complete mould room. Teaching responsibilities include radiation therapy residents (4), radiation therapy technology students, and medical students. The hospital has a NCI-funded CCOP program with a RTOG affiliation and has research facilities on site for basic and clinical research. Send curriculum vitae to:

Peter A. Fleming, M.D.
Head, Division of Radiation Oncology
ALLEGHENY GENERAL HOSPITAL
320 E. North Avenue
Pittsburgh, PA 15212

An Equal Opportunity Employer M/F/H/V

AGH
ALLEGHENY GENERAL HOSPITAL

For Sale
Dental X-ray Machine

Siemens — Orthopantomograph 3 with Nanodor 2 Generator in full working order. Offers requested in the region of £2,250.

For further information and arrangements to view please contact: Mr J.F. Hogg, Div. Superintendent Radiographer, X-Ray Dept., East Birmingham Hospital, Bordesley Green East, Birmingham B9 5ST. Tel: 021 772 4311. Exts. 4090/4381.

THE BRITISH JOURNAL OF RADIOLOGY

All enquiries for advertising space should be addressed to:

Advertisement Dept, The British Journal of Radiology, 36 Portland Place, London W1N 4AT. Tel.: 01-631 1168, 01-580 4085

British Journal of Radiology Supplement 19

Radiation Damage to Skin

Fundamentals and
Practical Aspects

Proceedings of a Workshop held at Saclay, France, on October 9–11, 1985, organised by the Commission of the European Communities and the Commissariat à l'Energie Atomique de Protection et de Sûreté Nucléaire, Fontenay-aux-Roses, France.

Skin and underlying tissues are frequently critical structures in radiological protection. Over exposure to ionising radiation can cause serious long-term suffering and disability.

Despite their practical importance, the dose-effect relationships, the pathophysiological mechanisms and the influence of the degree to which different tissues are involved are still poorly understood.

This Workshop and Proceedings bring together those at the forefront of research in these areas from all over the world. They review the present state of knowledge and attempt to identify specific problem areas which may lead to recommendations for the improvement of radiological protection and for the better management of radiation accidents.

Radiation Damage to Skin is, therefore, a vital reference work for everyone working in radiation protection and dosimetry.

Price £18.00 including postage and packing. About 200 pp.; illustrated.

ISBN 0-905749-13-8
ISSN 0007-1285

Orders to: The Publications Department, The British Institute of Radiology, 36 Portland Place, London W1N 3DG. Tel: 01-580 4085.

**PRINCESS MARGARET
HOSPITAL FOR CHILDREN
PERTH, WESTERN AUSTRALIA**

CLINICAL STAFF

DIRECTOR OF DIAGNOSTIC RADIOLOGY AND IMAGING

(FULL TIME)

Applications are invited from appropriately qualified and experienced medical practitioners for the above full time position.

Applicants must be eligible for full registration with the Medical Board of Western Australia.

Experience in all aspects of Paediatric Radiology, including CT and Ultrasound, is essential. Experience in Paediatric Nuclear Medicine would be an advantage.

GENERAL
Princess Margaret Hospital for Children is the sole paediatric teaching hospital in Western Australia and is integrated with the University of Western Australia and the Princess Margaret Medical Research Foundation. It has 257 beds with approximately 16,400 admissions and 154,000 outpatient attendances. The Diagnostic Department was completed in 1984.

The Diagnostic Imaging Department provides for all aspects of general plain film radiology, procedural radiology with angiography and interventional radiology. General ultrasound, echocardiography, nuclear medicine and CT scanning are also carried out in the department. 25,000 examinations were performed in 1986. The department conducts clinico-radiology consultation programmes within the Hospital and also participates in undergraduate and postgraduate teaching programmes.

SALARY & CONDITIONS OF SERVICE
In accordance with the West Australian State Public Hospitals Medical Practitioners Award, 1987.

The position carries the right to join the state Government Superannuation Scheme or a subsidised endowment assurance scheme.

FURTHER DETAILS
May be obtained by telephoning the Medical Director on (09) 382 8245. A memorandum of information is available.

APPLICATIONS
Written applications with the names and addresses of three (3) professional referees should be lodged with the Medical Director, Princess Margaret Hospital for Children, GPO Box D184, Perth, W.A., 6001 and received by Friday 27 November, 1987.

**PRINCESS MARGARET HOSPITAL
TORONTO, CANADA**

CHIEF, DEPARTMENT OF IMAGING

The department is responsible for all professional radiologic and nuclear medicine services at the Princess Margaret Hospital, a provincial cancer hospital with 202 beds. The PMH has a service program in radiation and medical oncology with surgical consultation, and a teaching and research program in oncology. Over 7000 new patients with cancer are seen each year together with 165,000 ambulatory care visits The hospital is in the process of rebuilding its facilities.

The chief should be an experienced physician/administrator with a strong commitment to clinical service, departmental administration, teaching and research. There are currently five professional members in diagnostic radiology, and one in nuclear medicine. Equipment includes CT, ultrasound, MRI.

Applicants should have certification in Diagnostic Radiology from the Royal College of Physicians & Surgeons (Canada) or equivalent, and demonstrated administrative skills as well as clinical. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents *For further details please write to:* Dr R S Bush, Director, Ontario Cancer Institute, 500 Sherbourne Street, Toronto, Canada M4X 1K9.

Diagnostic Radiologist

A diagnostic radiologist, at least at senior registrar level, is wanted, to serve one year in visiting professor status in the Department of Radiology at Texas Tech University School of Medicine. Will do general diagnostic radiology, including angiography and interventional procedures.

Send curriculum vitae and three letters of reference to:

**Lloyd K. Mark, M.D.
Professor and Associate Chairman of Radiology
Texas Tech University School of Medicine
4800 Alberta Street
El Paso, Tx 79905
USA**

NEW IMAGING BOOKS

Transvaginal Ultrasonography
TIMOR-TRITSCH/ROTTEM

This important new book is the first comprehensive work to deal with a major new imaging technique as a key diagnostic modality in obstetrics and gynaecology.

Illustrated with a wealth of startlingly clear pictures derived from the revolutionary 6.5 MHz probe, this book shows how the practitioner can use this technique.

Applications include early and accurate examination of ovarian tumours, imaging of early pregnancy and investigation and management of infertility.

176pp, cased, illus £29.95

Computed Cranial and Spinal Imaging
A Practical Introduction
STEVENS/VALENTINE/KENDALL

A lavishly illustrated book describing the theoretical and practical aspects of CT and MRI, their strengths and limitations as imaging modalities and their roles in the imaging of individual disease states.

224pp, limp, illus £24.95

Paediatric Diagnostic Imaging
GYLL/BLAKE

"The standard of paediatric radiography in general hospitals can be improved only by knowledgeable senior radiographers and by radiologists who are aware of how the radiographs on which they report have been produced. This book has substantially assisted in achieving this aim."
The Radiographer

240pp, cased, illus £29.95

Heinemann Medical Books

22 Bedford Square, London WC1B 3HH (01) 637 3311

UNIVERSITY OF CAPE TOWN

The Nellie Atkinson Chair of Radiotherapy

Applications are invited from suitably qualified registered medical practitioners for the above Chair, vacant from 1 January, 1988.

The successful applicant will be Head of the Radiotherapy Department at Groote Schuur Hospital and should have appropriate experience in teaching and research.

The appointment is a joint one between the University and the Cape Provincial Administration and will be at a fixed salary of R62,199 per annum with an annual bonus and attractive staff benefits. In addition, a non-pensionable allowance (currently R8,475 per annum) is payable by the provincial authority under certain circumstances.

Applicants should submit a full curriculum vitae and the names and addresses of three referees, not later than 13 November, 1987, to the Registrar (Attention: Appointments Office FJ 1887), University of Cape Town, Rondebosch, 7700, Republic of South Africa. Further information may be obtained from the above or from the Secretary, SA Universities Office, Chichester House, 278 High Holborn, London WC1V 7HE.

The University's stand against apartheid and all racially discriminating legislation is on record. Information on this as well as on the University's policy not to discriminate in the appointment of staff or the selection of students on the grounds of sex, race or religion is obtainable on request.

Bates Wells Recruitment CT ● 265R

LECTURE and MEETING FACILITIES

Available for hire
36 Portland Place, W1

Fully equipped air conditioned Lecture Theatre with seating capacity for 100 people.
Very attractive Library with Adam decor available for functions, buffets etc., capacity approximately 100.

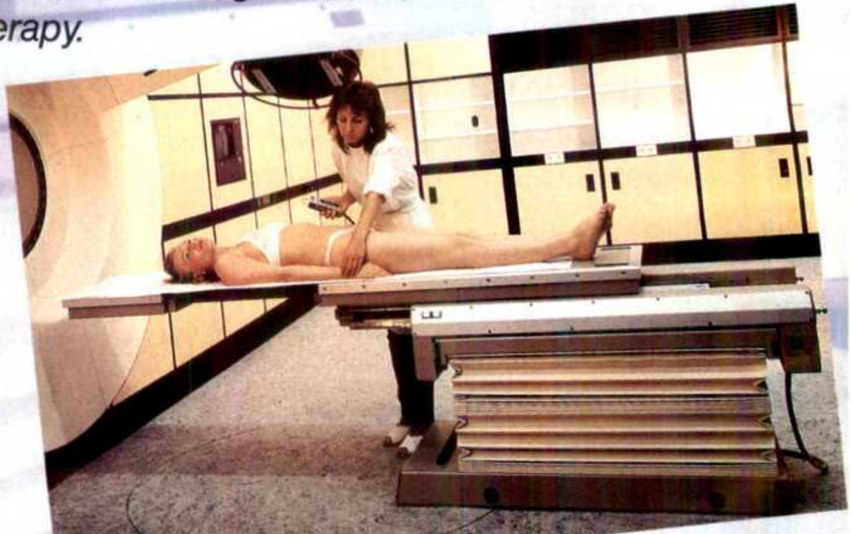
For list of charges please apply to the General Secretary, British Institute of Radiology, 36 Portland Place, London W1N 4AT or telephone 01-580 4085

Brown Boveri sets new standards: for example the DYNARAY-CH patient support unit.

Before we set about developing the treatment table for our linear accelerators, we had long discussions with the people who would have to work with it every day, i.e. with radiographers, treatment planners and therapists. The result is a table with features which fulfil all possible requirements not only now, but in the foreseeable future.

The advantages start already at the time of installation, because only a low-cost, 20 cm deep pit has to be built. Nevertheless the height of the table can be varied between 53 cm and 170 cm above the floor—the high-precision scissor design makes it possible. Also the extreme longitudinal movement of 160 (optionally even 190 cm) is not so easily matched. This range was chosen with dynamic therapy in mind. Actually, all therapy movements are firstly motorised and secondly prepared for a second verification channel, something which is essential for safe dynamic therapy.

The table movements are included in the accelerator's assisted set-up system. Simple operation of push-buttons enables the table top to be floated in the two main axes.



We don't just promise it—we have it!

British Brown-Boveri Ltd.
Darby House, Lawn Central
Telford, Shropshire TF3 4JB
Telephone (0952) 502 000

or:

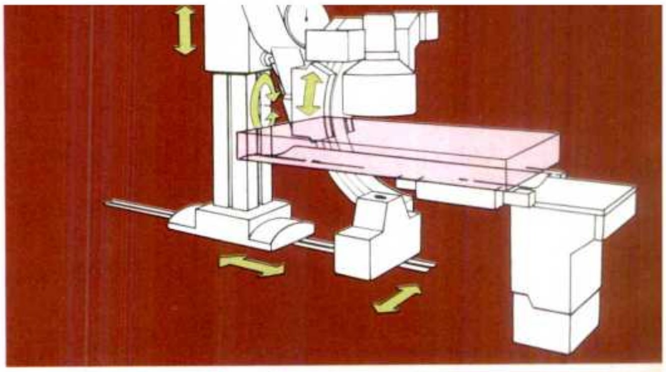
BBC Brown, Boveri & Company, Ltd.
Information Technology
CH-5401 Baden/Switzerland
Radiotherapy Department
Telephone 056/75 45 04 or 056/75 11 11

BBC
BROWN BOVERI

CH-IT 5024 87 E

The Philips DIAGNOST ARC optimizes the advantages of the C-arm concept through a special mounting permitting virtually unobstructed access to the patient. As all movements are realised by the beam carrier, the patient remains safely stationary throughout the examination.

The isocentre of rotation and angulation can be placed anywhere in the patient, allowing all practical projections through any part of the body. Automatic beam stepping allows the flow of contrast medium to be followed with ease, even for peripheral angiography.



Step into advanced angiography with all-round confidence

A large-format film changer can be added if required and, in this case, techniques can be interchanged at the touch of a button.

This is the system of choice for Angiography which is especially suitable for use with DSA equipment.

Philips Medical Systems
Kelvin House
63-75 Glenthorne Road,
Hammersmith,
LONDON, W 6 OLJ

Medical Systems

PHILIPS

British Journal of Radiology Supplement 20

The Safety of Diagnostic Ultrasound

Edited by Professor P N T Wells

In 1984 the Diagnostic Methods Committee of the British Institute of Radiology set up a working group to review the scientific evidence concerning the safety of diagnostic ultrasound. The group included representatives of the British Medical Ultrasound Society, the College of Radiographers, the Institute of Physical Sciences in Medicine, the Royal College of Radiologists and the Royal College of Obstetricians and Gynaecologists.

BJR Supplement 20—**The Safety of Diagnostic Ultrasound**—is the full report of that working group and includes:

- review of exposure conditions
- biological effects reported following exposure to diagnostic ultrasound
- the effects of ultrasound at diagnostic intensities on animal reproductive tissue
- the biological effects of high-level ultrasound of relevance to diagnostic exposure conditions
- human epidemiological data

The Safety of Diagnostic Ultrasound is a timely and authoritative review—essential for anyone involved in ultrasound today.

ISBN 0-905749-14-6
ISSN 0007-1285
Published 1987

Price £6.00 including postage and packing
Approximately 48 pp.

Orders to: The Publications Department, The British Institute of Radiology, 36 Portland Place, London W1N 4AT. Tel: 01 580 4085.

British Journal of Radiology, Supplement 21

Radionuclides in Brachytherapy: Radium and After

Edited by N G Trott

This Report, prepared by a multidisciplinary working party set up by the British Institute of Radiology, reviews the clinical, dosimetric, radiobiological and practical aspects of brachytherapy using γ- and X-rays emitted by both natural and artificial radionuclides.

Radionuclides in Brachytherapy is a comprehensive introduction to the current state of the subject, as well as giving the background to the changes in techniques that have taken place during the last 40 years. Including tables, illustrations, a glossary and an outline of ICRU and BCRU recommendations plus a helpful list of manufacturers and suppliers, this report will be indispensable for anyone involved in theoretical or practical aspects of the radiotherapy, radiobiology or dosimetry involved in this method of treatment.

ISBN: 0905 749 15 4
ISSN: 0007 1285
Publication date: October 1987

Price: £12.00
Approximately 70 pp

Orders to: The Publications Department, The British Institute of Radiology,
36 Portland Place, London W1N 4AT.
Tel: 01 580 4085

1987, *The British Journal of Radiology*, *60*, 947–955

VOLUME 60 NUMBER 718 OCTOBER 1987

The British Journal of Radiology

The institute at 90: a time for reappraisal?

British Institute of Radiology Presidential Address, 1987*

By R. J. Berry, Q.H.P., R.D., M.A., D.Phil., M.D., F.R.C.P., F.R.C.R., F.A.C.R.(Hon.)

Department of Oncology, Middlesex Hospital Medical School, London W1P 7PN

(*Received July 1986*)

It is fairly awesome for a President to cast his eye down the list of those who have held this Office in the past. When compiling the Presidential Address he is in the condition ascribed to one of Elizabeth Taylor's later husbands, "He knows what he has to do, he knows what he wants to do, the problem is how to make it interesting!" More especially, a President who actually elects to give his Address on All Fools Day before noon takes his life totally in his own hands!

I would hope that you would recognise the Institute's logo, which is displayed inside the front cover of every issue of the *Journal* as well as on the Presidential Badge. The important words are at the bottom, "Founded in 1897". The Institute is now 90 years old and also 90 years *young*. Roentgen discovered X rays in November 1895, the discovery was published in German the following month but it was not until January 7, 1896 that the first English publication appeared in the *Standard,* which was then a morning newspaper. On that very day, Campbell Swinton achieved the first radiograph ever produced in the UK (Holland, 1937). The potential for the application of the new rays to medicine was obvious and recognised early, and the important thing was that the scientist and the doctor were at the frontier together. The *Standard,* quite interestingly, found it necessary to reassure its readers in the announcement of the discovery of X rays, that "... there is no joke or humbug in this matter, it is a serious discovery by a serious German Professor". By April 1896, the *British Medical Journal (BMJ)* had appointed a special commissioner, Sydney Rowland, to investigate and report "on the application of the new photography to medicine and surgery". It was he who published the first report of harmful effects of X rays in the *BMJ* of April 18 (Rowland, 1896). Rowland was actually a very interesting character; his period of interest in radiology was relatively short—he was really a microbiologist—and he was sadly to die in the First World War of meningitis when serving in France with the Royal Army Medical Corps (RAMC) (Jupe, 1961).

Most of 1896 appears to have been occupied with building better X-ray-producing apparatus, but by 1897 the machines worked much of the time and now a few medical men began to see a need for a society for the systematic study of these new phenonema and the turning of the X rays to some practical use. On March 18, 1897, there was a small private meeting of Drs Fenton, Harrison Low, Walsh and, we think, Sydney Rowland, with Dr Low in the chair. We know that it took place at the house of the Medical Defence Union which was then in King William IV Street just off the Strand. The building is no longer there, but it was directly opposite the old Charing Cross Hospital, which is sadly in the process of being demolished at this moment. That was just about the geographical centre of British medicine at that time because the Royal College of Physicians was just the other side of Trafalgar Square in Pall Mall. How the centre of gravity has sinced moved(!), but it is pleasant to note that the Institute and the Royal College of Radiologists are still near neighbours of the RCP. Dr Walsh was appointed temporary secretary and prominent members of the medical profession were written to, asking if they would join a Society for the study of the X rays if one was formed. At a further meeting on April 2, 1897, it was unanimously decided that there was a need for such a society and an advertisement was placed in the *BMJ* on April 10.

> "At a meeting of medical men interested in the X ray, held last week at 20 King William Street, Strand, rules were drawn up subject to final approval at a large general meeting. It was resolved that membership should not be restricted to medical men but should include all who are interested in the scientific study of the Roentgen rays. The difficulty of discussing medical matters before a mixed audience will probably be got over by forming a medical subsection. Any inquiries may be made of the Honorary Secretary, Dr Walsh, 5 Pump Court, Temple, E.C."

Thus began the Roentgen Society, almost exactly 90 years ago. I am very much indebted to the *Journal*

---

*Delivered at the BIR 1987 Annual Congress, Southampton, April 1, 1987.

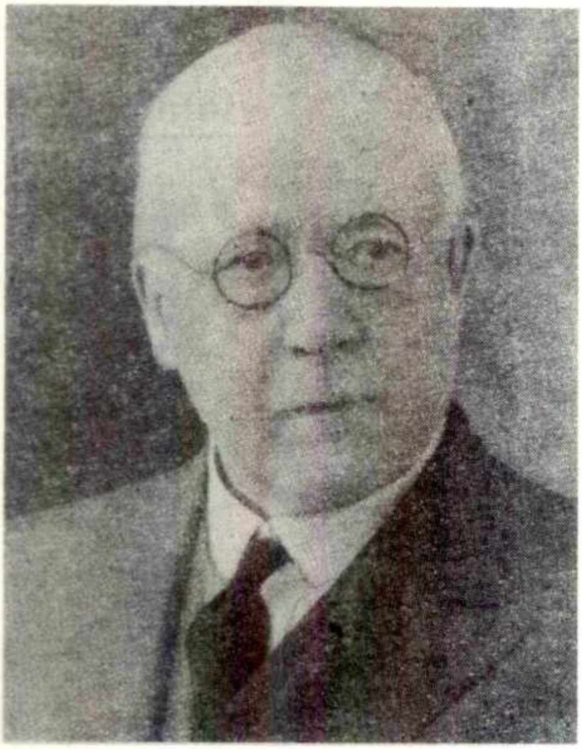


FIG. 1.

Dr David Walsh, first Honorary Secretary of the Roentgen Society (from Landes & Hall, 1984).

Managing Editor, Lynn Whitfield, for having passed to me a letter from the *Journal of the American Medical Association* which contained a great deal of information about the Society's first Honorary Secretary, Dr David Walsh (Landes & Hall, 1984). Figure 1 shows the best picture that we have found of him. He was apparently quite a character and lived to the age of 90, dying only in the 1940s. Walsh remained Honorary Secretary of the fledgling Roentgen Society throughout the rest of his active career. He was Edinburgh-trained, and published the first actual scientific paper on X rays in medicine in English; he was apparently pretty quick off the mark as it was published in the *Medical Press* on January 8, 1896, the day after the article in the *Standard* announcing Roentgen's discovery. However, his book *The Roentgen Rays in Medical Work* (Walsh, 1897), a more serious contribution, went through four English editions and three American editions and was considered a classic right up to the time of the First World War. He is described as having been argumentative and bellicose, and had very few friends, but he certainly had the ability to make things happen. Interestingly, from the address cited in the *BMJ* article, his rooms were in Pump Court in the Temple. I didn't think doctors penetrated into that legal fastness, but 5 Pump Court still very much exists, and I have walked past it on my way to HMS President, the London Division of the Royal Naval Reserve, every week for at least the last 15 years without noticing the inscription beneath the sundial set high in the wall of Pump Court, "Shadows we are and like shadows depart". How appropriate for a pioneer of the use of X rays.

The first general meeting of the Society was held on June 3, 1897, in the rooms of the Medical Society of London in Chandos Street, another body still very much alive, and at that stage the name of the new society changed from the X-Ray Society, as had first been decided, to the Roentgen Society to commemorate the man who had discovered X rays. It was decided that Sylvanus Thompson should be its first president and that was a very wise choice. Interestingly, we now find that it was not the first choice, because Walsh had written to Lord Lister enclosing a "draft of rules" for the new Society and apparently offering him the presidency, to which Lister replied "... the subject, though undoubtedly of extreme interest to physicists and very important to medical practitioners, is of somewhat too limited a character to found a society for" (Landes & Hall, 1984). Anyhow, the choice of Sylvanus Thompson was a brilliant one, and so was the idea that it was going to be a society equally divided between those who were medical and those who were non-medical. This was clearly set out in an address by an early Honorary Treasurer, J. J. Vezey, to a General Meeting of the Society in 1904; he was a Fellow of the Royal Microscopical Society, and clearly not a medical practitioner. Speaking of the equal division in the first list of Vice-Presidents and members of Council between medical men and laymen, he remarked:

> "This is not to be wondered at because up to that period few medical men had made a special study of electricity and scarcely any of them possessed the necessary apparatus—such as a large induction coil to carry on the experiments—while a large number could not possibly spare the time for the necessary investigations;" (and it was *not* because of their busy private practice—or was it? *plus ça change ...*). "They therefore sought out their scientific friends and invited their help and co-operation which was most readily given, and the meetings of the Society testify to the mutual work and co-operation of the lay and medical members. I particularise this point just now because it has recently been suggested by some who have not grasped the spirit of the society that the lay members have desired to invade the province of the medical man. Nothing could be further from the truth. And I am quite sure the majority of our medical members would bear testimony to the fact that the lay members have always been willing to render them any assistance without obtruding on their special functions. I do not wish to press this point unduly but before leaving it, I would remind you that the action of electricity on the body and its functions is principally physiological. Some of the

most eminent physiologists have been laymen and it is largely to their discoveries that we are indebted for the principal part of our knowledge on this important subject." (Vezey, 1904).

The objects of the Roentgen Society as formed were "The study of the nature of the rays, a practical enquiry into the best apparatus for their production and an investigation of all details bearing on their useful application." Its formal inauguration was on November 5, 1897, and this was very much a society occasion. It was held in the old St Martin's Town Hall, now sadly totally lost to history (again in the Charing Cross area). I can find no picture of it at all but apparently it was a fairly grandiose building of the 1850s and the suite of rooms that was taken for the occasion was apparently suitably grand. There were members of the aristocracy there, and I am delighted to see there were even a Mr and Mrs Berry in the list of those who were there. Sylvanus Thompson was one of those rare communicators—he was what we would today call charismatic—and his Presidential Address, which was an attempt to try to take this very mixed audience through how the X rays were discovered and what they would do, was apparently a triumph of teaching physics to the uninitiated. There is a marvellous article in the *Archives of the Roentgen Ray* (Anonymous, 1897), as it was by then, the journal (it started as the *Archives of Skiagraphy*) which eventually became of the *British Journal of Radiology*, in which the events of that memorable evening are described.

> "On the walls of the hall a large number of radiographs were displayed forming probably the most advanced and representative collection that has yet been brought together. The progress that has been made in methods and apparatus could be strikingly realised by comparing the wonderful finish, definition and detail of these pictures with the fuzzy specimens of early work that less than two years ago all the world wondered at. Nearly all the most prominent manufacturers had tables assigned to them for the display of instruments; coils, focus tubes, batteries, contact breakers, fluorescent and intensifying screens, photographic films, all appeared in endless variety and brought under view the entire arsenal of the X ray apparatus."

The pattern is little changed today, with a Technical Exhibition which forms an integral part of the Institute's Congress. However, back to 1897:

> "Through the voluntary efforts of one or two members of the Council an excellent musical programme was provided, the concert being opened by a Mr W. Webster whose magnificent voice appeared much to advantage in 'Il Sono' by Mercadante with a 'cello obbligato played by Mr Prosper Burnett. The latter afterwards charmed the audience by his sympathetic rendering of Goddards's well-known 'Berceuse'. Miss Cordelia Grill sang songs by Schumann and Meyer Helmund with great taste and feeling. The next item was a masterly rendering by Mr S. Webbe of 'Liebestraum' (No. 4) by Liszt. Lastly came two songs by Mr Henry Piercy which delighted a large number of appreciative listeners. Owing to the lateness of the hour and much to the disappointment of the audience, it was found impossible to carry out to the end this excellent and well-arranged programme."

We have not arranged a musical programme for you as part of the 1987 Congress, but tonight the Solent City Jazzmen will play at the Civic Reception in Southampton's Guildhall.

> "In the small hall, lantern demonstrations were given throughout the evening and darkrooms were arranged for screen work. Here many may have seen for the first time a living heart in action. In the lower hall, short lectures and demonstrations were given on different residual gases *in vacuo*. Tubes containing various fluorescent and phosphorescent materials such as calcium tungstate and sulphide, dolomite, coral, foraminiferous marble, etc., were shown at work. It was not until 12 o'clock that the greater part of this interested and appreciative assembly dispersed."

—they were tougher then than we are now! The inaugural meeting testified to the great and growing interest that centred around the Roentgen Ray, and the Roentgen Society was very much a success right from its formal start on November 5, 1897.

The next major step which altered the future of the Institute was the formation of that great panjandrum for postgraduate medicine, the Royal Society of Medicine (RSM), by the coalition of a number of independent medical societies. Having started with the Roentgen Society which was a mixture of scientists, lay people and medical men, an all-medical society had been formed in 1902, the Electrotherapeutic Society. This was largely because it was being recognised by then that the Roentgen rays had therapeutic value as well as being of diagnostic interest, and that was felt to be totally the province of the medical man. It is rather sad to find that in fact it was the forebears of my own colleagues, the embryo radiotherapists, who led the drift away from the multidisciplinary Roentgen Society to an all-medical society. That Electrotherapeutic Society then became the Electrotherapeutic Section of the Royal Society of Medicine when the RSM was formed in 1905, and was the precursor of the present Radiology Section of the RSM.

The next big change came with the Great War in 1914. British medicine in general, but the RAMC in particular, was disastrously unprepared for the use of X rays. It was so clear that the X rays were going to be

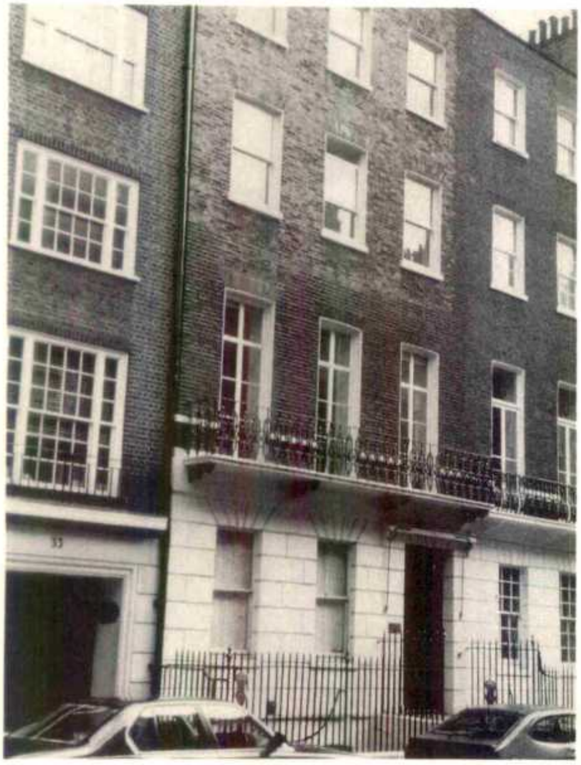


FIG. 2.

32 Welbeck Street, London W1, the home of the British Institute of Radiology for 60 years.

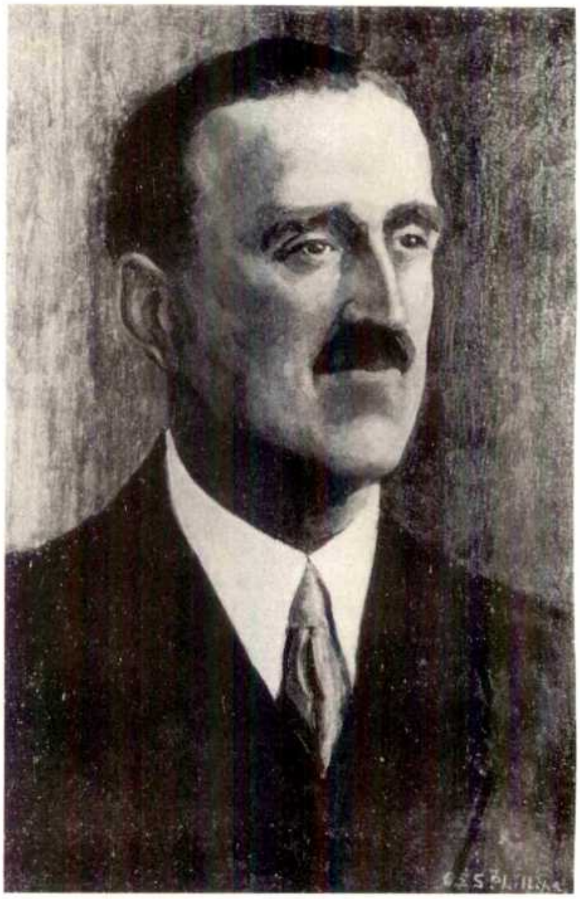


FIG. 3.

Sir Archibald Reid, "architect" of the Institute's first home, painted from memory by Major C. E. S. Phillips.

important in battlefield medicine, but somehow the training wasn't there, the idea that there should be specialist radiologists wasn't yet there. There was clearly a great need for proper training of radiologists. By 1917 Cambridge University had proposed a Diploma in Medical Radiology and Electrology and, uniquely, they waived for this diploma the usual requirement that students should be resident in Cambridge. However, although they were prepared to let the diploma be taught and be examined for and by non-residents, the trouble was that *somebody* had to organise teaching for it. At this stage there was a coalition now between the Radiology Section (as it become) of the RSM and the Roentgen Society, in which members of both joined together to produce a new (but purely medical) society, the British Association for the Advancement of Radiology and Physiotherapy. It was incorporated in 1921 and it very quickly acquired a house, 32 Welbeck Street, as its home in 1922. By 1924 there was great pressure to widen its remit, and it changed its name to the British Institute of Radiology. This followed in the wake of the creation of the Institute of Physics by the co-operation of five separate scientific societies whose interests had grown together (the Roentgen Society was one of these, but it did not merge entirely into the new Institute of Physics), and was the result of the idea then current that an "Institute" was something *more* than a scientific society. By 1927 the Roentgen Society, totally multidisciplinary from its inception, was now amalgamated into a single body with the medical group who were also back together in a single society, the "British Institute of Radiology (incorporating the Roentgen Society)". Within that same year the Society of Radiographers also associated itself with the Institute, so that by 1927, the intellectual and practical centre of British radiology was the British Institute of Radiology.

The acquisition of 32 Welbeck Street (Fig. 2) was due primarily to the efforts of a remarkable man whom we honour too little, Sir Archibald Reid, whose picture hangs in the Institute's lecture theatre (Fig. 3). It is not a particularly outstanding picture except for the fact that it was painted from memory many years later, in 1937, by another of the pioneers of the Institute, Major Charles Phillips. Reid died suddenly in the year of the acquisition of the House; 32 Welbeck Street was nearly next door to his own home and it was he who found it, he who provided the almost reckless drive to acquire it, and he who moved in the first orange crates to sit on because there was no furniture in the building. He was an amazing man, the founder of British Army radiology, amongst many other achievements (Barclay, 1925).

The bringing together of the Societies really was important. There was a marvellous letter to *The Times* (letters to *The Times* actually had some impact in those days) by Stanley Melville (Melville, 1927), who was at that time the medical secretary of the Roentgen Society and of the new Institute and he wrote:

> "The coalition of forces of the British Institute of Radiology with those of the Roentgen Society is one of far-reaching character and a bold democratic stroke. The combination is a triple one comprising the medical man, the physicist, and the engineer and manufacturer. For the first time in the history of radiology it will now be possible for the doctor to work not only in combination with the physicist but with the very man who is able to carry out in practical form the requirements of both and also to supply highly technical knowledge from the standpoint of each branch of the coalition for the common good. The possible results may be prodigious." (Had he forgotten, that's how the Roentgen Society started 30 years earlier!). "When it is realised that two weeks ago for the first time a large and important exhibition, solely of British manufactured apparatus, was held in the Central Hall, Westminster, the possibilities of the future may be gauged. Every advance will now be a combined effort of three parties to the alliance, all working for one common cause and that the good of humanity." But nothing has really changed in 60 years, because the next paragraph says "All that is now wanted is for the necessary funds to be forthcoming from the great-hearted and far-seeing philanthropists who will have absolute assurance that any funds will be administered for the advancement of radiology to the benefit of Great Britain in keeping her place in the forefront of radiological science."

That is one of the fascinating things about history, we do sadly repeat ourselves.

As a home for the Institute, 32 Welbeck Street was a marvellous place and worked terribly well. It had been the old Imperial Russian Embassy, and had some eclectic features of an architectural style which can only be called indeterminate. Its lecture theatre, the Reid–Knox Hall, had been a Russian Orthodox chapel, and has now been restored to its old magnificence by the house's new owners, the Variety Club of Great Britain. It was a splendid place in which to lecture, although I am grateful that by the time I joined the Institute the original "sit-up-and-beg" seating had been replaced by very comfortable modern theatre seats, thanks to the generosity of one of the Institute's early industrial members, Mr Cuthbert Andrews. With just over 90 seats and its miniscule gallery, it had a very nice feel about it and in a way in our modern setting we do miss it. The new Institute also housed a radiological library. The first germ of a library was Sir James Mackenzie Davidson's personal collection of books. It formed the nucleus of the British Institute of Radiology library which today is one of the great radiological libraries in the world. That position is under threat for the future because of the tremendous increase in the volume (and cost) of radiological literature. It is one of the areas in which the Institute must concentrate its efforts for the future to make sure that we do sustain it as it should be, a treasure-house for our successors.

But radiology was international and, in 1925, the first International Congress of Radiology was held in London under the Presidency of Thurstan Holland. In 1928, at the second Congress which was held in Stockholm, the British Institute of Radiology presented the Presidential Badge which is still worn by the President of the International Congress of Radiology and of the ISR. The Institute was right at the centre of world radiology as well as British radiology.

In the 1930s, 32 Welbeck Street was a very happy house. It was the centre of British radiology science and it was multidisciplinary at its core. But at its core every apple has its worm and there were forces playing again which, while they have in many ways resolved to the good, nonetheless at the time were looked at as very threatening. An advertisement was placed in the *British Journal of Radiology* in 1937 and an editorial commented on it (Anonymous, 1937):

> "We would draw the attention of our readers to two advertisements appearing on pages . . . The first is a routine advertisement announcing the dates for the Cambridge Diploma Course for 1937–38; a footnote states, 'The University has decided that the Diploma shall cease to be granted after 1941 . . .' The termination of the Cambridge Diploma will be regretted by all radiologists for in its relatively short career it established a standard of radiological education which has been followed by practically all countries." (And it was the Institute that provided the London teaching course for the Cambridge Diploma). "The second advertisement announces the first examination for the Fellowship of the British Association of Radiologists. It is emphasised that candidates for the examination must hold a radiological diploma of a recognised university. The British Association of Radiologists is a medical body and one of its chief objects is the establishment of a higher qualification in radiology. It was inevitable that sooner or later a development of this kind would arise; as science advances and expands, the need for deeper and longer study increases and with this the need for a higher examination. In initiating a

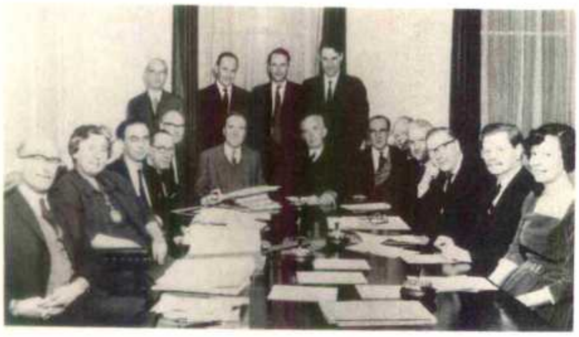


FIG. 4.
The Institute's Council, 1965–66, Miss M. D. Snelling in the Presidential Chair.

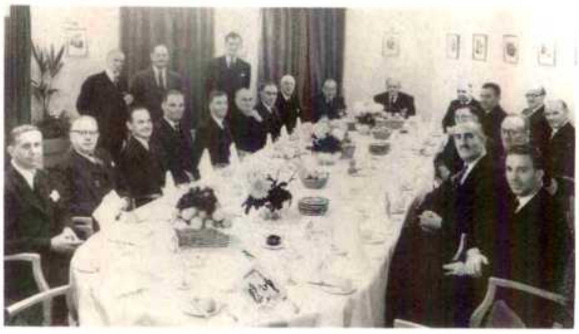


FIG. 5.
The President's Dinner, 1957, Kettner's Restaurant, Soho.

Fellowship, the British Association of Radiologists is following the example of other special branches in medicine, notably the College of Obstetrics, whose Membership and Fellowship have proved a striking success. Clinical medicine, surgery and pathology have been included in the curriculum of the British Association of Radiologists. This is an excellent innovation and, as the *British Medical Journal* states, the medical profession will welcome the step that has been taken to consolidate the educational equipment of the radiologist."

This, of course, was the beginning of what has become the Royal College of Radiologists. Certainly no-one would now quibble at the need for a truly medical body with responsibility for standards of medical training in the specialty of radiology, but it was very difficult at the time and was fraught with considerable pain that, once again, the function and even the being of the multidisciplinary body of the British Institute of Radiology was, in large part, apparently being threatened by the advent of a new and totally medical radiological society.

The Second World War now intervened, and with the dramatic changes in radiodiagnosis and radiotherapy—and the basic science which supported them—32 Welbeck Street remained the intellectual centre not only of the radiological world, but also of the new discipline of medical physics. It was an exciting time. I first came to England in the late 1950s and my early introduction to the Institute's meetings was very different from the way they are today. The meetings took place monthly on a Thursday evening, and the platform party wore dinner jackets. At the Annual General Meeting there was a sort of ritual of coming of age that every Honorary Secretary had to face (I suffered this even in 1970–73), that the Annual Report was *read* to the Annual General Meeting! The test of skill was to do it as quickly as possible but still be intelligible—my native American rate of speech did help a bit, I must admit! Figure 4 shows a meeting of the Council of the Institute in 1965–66, in the old Council Room in 32 Welbeck Street. My erstwhile Middlesex colleague, Margaret Snelling, was in her Presidential year, flanked by another ex-president, George du Boulay who was then Honorary Medical Secretary, and our just-retired *Journal* Editor John Haybittle looking a very young man sitting on the corner, as the Honorary Non-Medical Secretary. That Council table still exists in our Council Room and, though I hate to say it, those Council chairs still do as well. Although they have been reupholstered, they're still no more comfortable! But, as you can see, it was then as it is now, a big and busy Council—and totally multidisciplinary. It worked well together.

Some traditions have had to disappear. Figure 5 is from a decade earlier and was kindly sent me by I. G. Williams, showing the annual Presidential Dinner for Council in his year, 1956–57 and held at the late, lamented Kettner's Restaurant in Soho. Next to him is Len Lamerton who was to be the President the following year; there are many familiar faces around that table. Those dinners are fondly remembered; the President still dines Council at the end of his year, but in more modest fashion in the Institute's house.

So, in the post-war period, the Institute was a very busy place. Science and medicine came together very closely indeed, but the era was coming to an end despite the tremendous expansion of radiology, the tremendous rush of new technology. The reason was 1984. Not in the Orwellian sense—now that we've passed it we don't seem to remember how much that year was graven on our hearts—but that was the year the lease on 32 Welbeck Street was to run out. Although the Institute had been very carefully setting aside year-on-year monies to redeem the lease, nobody could have foreseen the tremendous post-war expansion of property values, the tremendous inflation which made savings, even however well husbanded—and they *were* well husbanded—essentially worthless. And so we had to face up to leaving 32 Welbeck Street. The cost of trying to pay for the delapidations demanded by the ground landlord would have been killing for the Institute, and no matter how pleasant its memories we would still have been in the same house with its limitations on

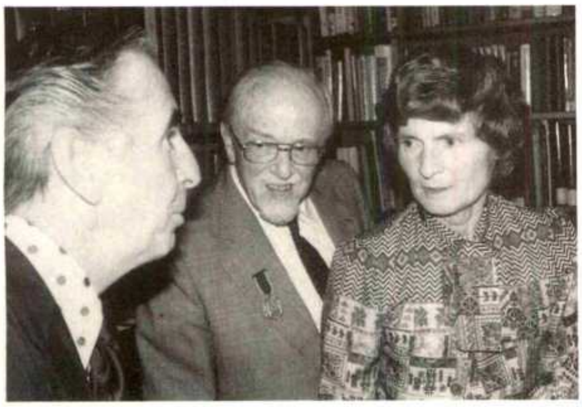


FIG. 6.
The farewell party in the library at 32 Welbeck Street, Douglas Currie speaking to Professor and Mrs V. W. Mayneord.

space for future expansion. So, reluctantly, we started looking for a new home. Sadly, because of this period of indecision, we were, in retrospect, weak and vacillating; at the time we seemed to be taking strong initiatives down clearly labelled tracks! But that is the joy of looking back on it. The Institute was not sure about its future, and in this period the growing confidence of the Faculty of Radiologists as it progressed to being the Royal College of Radiologists changed subtly the relationship between the two organisations. When the College acquired its home in Portland Place the Institute was still homeless. There really was a serious fear that the Institute was going to disappear—what did we need it for anyway in this changed world? There was no real future. We had not actually found our way, and what marvellous light at the end of the tunnel it was when a home was found, and how great our gratitude to the generosity of those within and without the Institute who made its acquisition possible. How right that home should be at 36 Portland Place, next door to the Royal college, to create what all of us had wanted so much, a true British Radiology House in which both the medical and the multidisciplinary societies could exist side by side, closely related to one another but nonetheless independent. We had to leave 32 Welbeck Street first though and that was a sad parting. Figure 6 shows the farewell party in the old library; past president Val Mayneord and Mrs Mayneord talking to Douglas Currie, the Institute's long-serving *major domo*. Douglas was one of the stalwarts of the Institute whom we all remember for so many years and wish so well in his well deserved retirement in Scotland. Meanwhile, the new home was coming along; builders were in. It didn't look like much when they started but as the structural work was completed and the Adam decoration was restored, so this marvellous building emerged and the British Institute of Radiology again had a home, with a first-class modern lecture theatre and a truly beautiful 18th century setting for its library. However, history repeats itself and, as with the amalgamation of the Roentgen Society with the British Institute of Radiology in 1927, we are in the awful position that we are still trying to pay for it. But it *is* the right house for us; it has the scale that we need to grow in the future, and leasing a substantial portion of it to the Parkinson's Disease Society and its mews cottage to a private tenant has brought much-needed income in the short term.

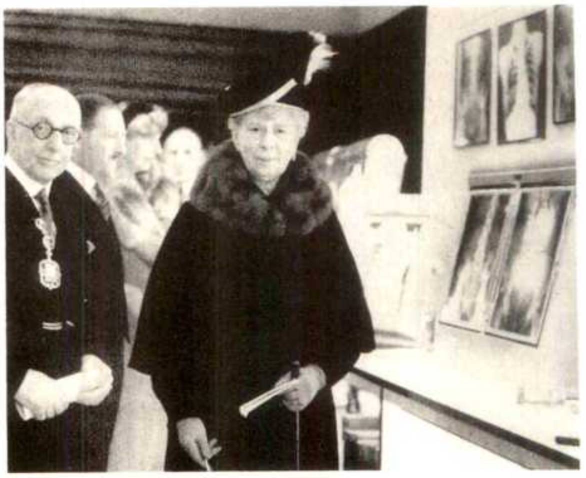


FIG. 7.
Her Majesty, Queen Mary at the 1937 Annual Congress of the British Institute of Radiology.

Another major factor in the Institute's development has been its Royal connection. Royalty took an early interest in X rays—but they were not always amused! At a meeting at the Grafton Galleries, Campbell Swinton, he who took the very first British X-ray picture, produced a picture of his own hand. Doubtless with great pride, it was shown to the then Prince of Wales, later Edward VII, who is reported to have said "How disgusting" (Swinton, 1930). However, by the 1930s, Royal approval was real and exactly 50 years ago Queen Mary visited the Annual Congress of the British Institute of Radiology (Fig. 7). I did try very hard to get the Queen to visit us here at "Radiology '87", the Institute's Congress in Southampton, but her schedule this month was rather too tight. Accompanying Queen Mary in the photograph is Russell Reynolds, who was President in that year; a marvellous man to whom I am very much indebted because he is one of the past Presidents who has looked back over the early history of radiology and given us a snapshot from which one can try to evolve the whole picture of how our Institute grew and developed—even if he did publish it in the Royal College's *Clinical Radiology* (Reynolds, 1961).

By the 1950s there was just that feeling "in the right quarters" as the saying goes that it might be appropriate to petition Her Majesty the Queen for a

LIBRARY

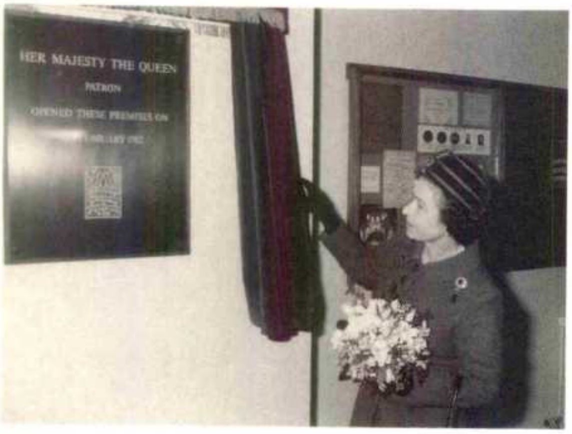


Fig. 8.
Her Majesty, Queen Elizabeth II opening the Institute's new house, 36 Portland Place, London W1.

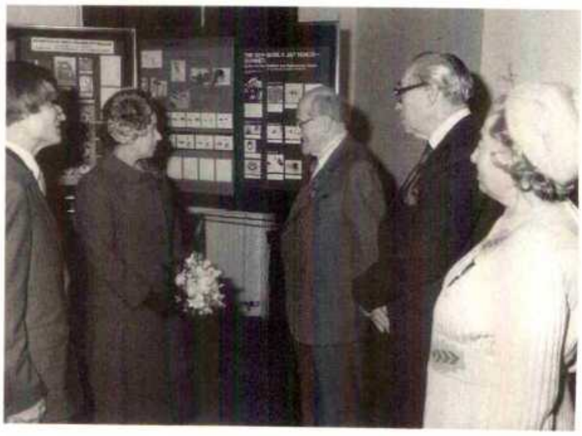


Fig. 10.
Dr Michael Day (left), President of the Institute 1981–82, presents past Presidents of the Institute, Professor V. W. Mayneord, Sir David Smithers and Miss Margaret Snelling, to Her Majesty, the Queen.

Royal Charter. It was carefully prepared; the groundwork of many years involved successive Councils. The petition was finally presented in 1957, and in 1958 the Royal Charter was graciously granted by Her Majesty the Queen. Nearly a quarter of a century later, the Queen graciously consented to open the Institute's new house in Portland Place and what a day it was! It tipped down with rain, but nothing could dampen either our spirits or the Queen's radiant smile. Figure 8 shows the unveiling of the commemorative plaque, and Figs 9 and 10 show members of the Institute staff and senior members of the Institute being presented to Her Majesty. Some of us had rather more difficult tasks; mine (Fig. 11) was to explain the Institute's history, in 10 minutes—and to make it interesting! I was rewarded by a burst of most gratifying Royal laughter.

What of the Institute's future, having viewed its eventful past? We are an active body today of over 1750 members, of whom about 400 are resident overseas. About 170 of our members are retired, but some 150 are in training so we are more or less in balance, despite unfavourable demography and the passing of the post World War II "bulge". Over the past few years there has also been a small but healthy trend of increase in numbers of members year on year. But I put to you, as I did in the circular letter which I sent round with your membership renewal form this year, that if each present member recruits just *one* new member, the financial problems of the Institute could be solved "at a stroke", to use a fine political phrase.

About 40% of our membership are diagnostic radiologists, some 25% are radiotherapists and

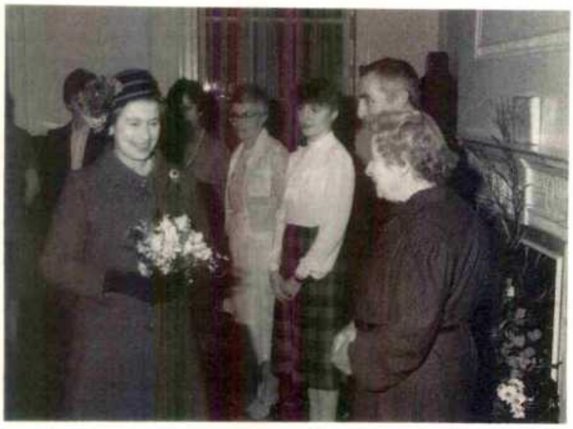


Fig. 9.
Her Majesty, the Queen speaking to Mr and Mrs Douglas Currie and other members of the Institute's staff.

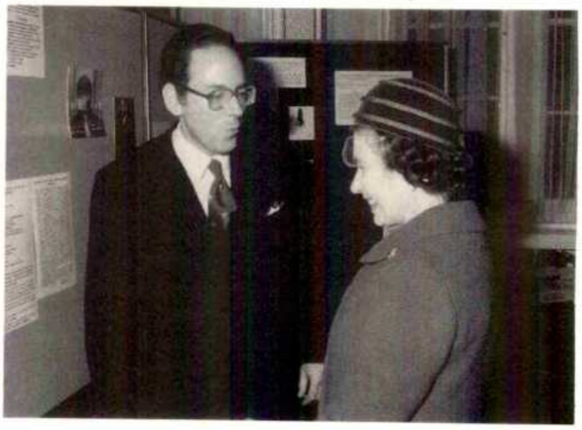


Fig. 11.
The author explaining the history of the Institute to Her Majesty, the Queen.

oncologists, about 10% are physicists, and the very important remainder consist of radiobiologists and other scientists, radiographers, engineers and other members of the X-ray industry. We still are what we started out to be, a truly multidisciplinary group. Radiology was of necessity a multidisciplinary activity right from the start. The Roentgen Society which evolved as its forum was a major force because it crossed not only scientific divides but social divides, because at that time the scientist, the engineer and the doctor were in different social worlds. Reading the literature of that time, it is amazing how disparate they were. The Inaugural Meeting of the Roentgen Society held on November 5, 1897 at St Martin's Town Hall was designed to attract a wide audience of lay people at the one end of the social spectrum, the aristocracy, and at the other, the "common" people who were actually making the new technology happen. It had a temendous cross-fertilising role, breaking down barriers at a time when in a fairly rigid Victorian society this did not commonly happen. The words of another Prince of Wales on the subject of scientific societies are fairly apposite: this was Edward, Prince of Wales, the uncrowned Edward VIII, speaking to the Royal Society of Medicine, but equally true for us:

> "Someone has said that society would be much happier if there were no Societies. I think the answer is that society is very well able to look after itself in this respect. If society finds that any one institution is no use to it, that institution very soon disappears. The law of survival of the fittest operates mercilessly where learned bodies are concerned and if a learned body fails to prove its worth, no amount of artificial feeding will prevent that learned body from speedily becoming a learned corpse which may not even get a decent burial." (Barclay, 1925).

What we call radiology today is a fascinating web of interlinked disciplines. The exponents of some of the different fields don't even think of themselves as "radiologists" anymore, but yet in so many ways they have much to teach each other if only they can communicate. They have much in common yet they believe it not to be so. I have said loudly on many occasions that I believe the most urgent danger to medicine and science today is that in the name of public accountability (and of course, like motherhood, who can be against that?), society demands more and more formal evidence of medical and scientific competence. We set up new diplomas, we then have to have teaching courses to support those diplomas and these entirely laudable aims are then subverted through a system of fragmentation as each new so-called specialty defines its boundaries, sets up its examinations and then once over the top pulls up the ladder behind it and says "in the interest of professional standards, you chaps aren't the same—but if you passed *our* examination . . .". Which brings us back to the Institute. Radiology? Perhaps the name radiology itself is outdated because what you see here at the Institute's Congress is an explosion of imaging; an explosion of the application of some of our technologies to the treatment of malignant disease; an explosion of new knowledge about radiation effects and risks; but all of us have common areas of scientific and medical interest. The name itself, radiology, may be too narrow but we don't know a better one to replace it. Certainly, I do not see us as a British Institute of Imaging, because imaging is only a part of the job we do. What role then for a multidisciplinary British Institute of Radiology, where membership is based on real commonality of interest, not because of professional status or advancement? The future of this Institute and, I believe, British radiology as a contributor to the world scene, depends on our ability to achieve synthesis of that which is best and most original in all our contributing disciplines. Ninety years on, the pattern and materials of radiological endeavour have changed almost beyond recognition, but a strong Institute remains. We are here today because the basic framework is right. Our strength is in our diversity, our future is in our enthusiasm.

REFERENCES

ANONYMOUS, 1897. Editorial. *Archives of the Roentgen Ray, 2*, 21–23.

ANONYMOUS, 1937. Radiological education. *British Journal of Radiology, 10*, 293–294.

BARCLAY, A. E., 1925. The history and future of British radiology. *British Journal of Radiology, Roentgen Society Section, 21*, 3–20.

HOLLAND, C. T., 1937. X-rays in 1896. *The Liverpool Medico-Chirurgical Journal, 45*, 61–77. Reprinted in *Classic Descriptions in Roentgenology* (1964). Ed. by A. Bruwer (Charles C. Thomas, Springfield, Illinois), pp. 70–84.

JUPE, M., 1961. Early days of radiology in Britain. *Clinical Radiology, 12*, 147–154.

LANDES, R. R. & HALL, S., 1984. A letter from Joseph Lister to Dr David Walsh. *Journal of the American Medical Association, 251*, 3101–3103.

MELVILLE, S., 1927. Radiology in medicine. *British Journal of Radiology, Roentgen Society Section, 23*, 302.

REYNOLDS, R. J., 1961. The early history of radiology in Britain. *Clinical Radiology, 12*, 136–142.

ROWLAND, S., 1896. Report on the application of the new photography to medicine and surgery. *British Medical Journal, i*, 997–998.

SWINTON, A. C., 1930. *Autobiographical and Other Writings*. (Longmans, Green & Co., London).

VEZEY, J. J., 1904. The Roentgen Society: its past work and future prospects. *Journal of the Roentgen Society, 1*, 2–8.

WALSH, D., 1897. *The Roentgen Rays in Medical Work*. (Balliere, Tindall & Cox, London.)

Book reviews

Diagnostic Imaging of the Chest. By Paul R. Goddard, pp xvi+173, 1987 (Churchill Livingstone, Edinburgh), £45.00.
ISBN 0-443-03659-4

This is a most unusual and in many ways very successful book. It is not, nor does it claim to be, a comprehensive review of chest radiology but it does provide a personal account of how chest problems are tackled in the 1980s at one of England's leading teaching centres. Particular emphasis has been placed on the impact made by computed tomography (CT): 38% of the 400-odd illustrations are CT images, only just behind chest radiographs (40%). Other new developments are assessed, including the role of nuclear medicine techniques and ultrasound.

Although the book is divided into sections (investigations, the solitary nodule, multiple coin lesions, miliary nodules, fibrosis, cavitation, opacification, consolidation, opaque hemithorax, decreased density, elevated diaphragm, pleural and chest-wall lesions, hilar enlargement and mediastinal mass), they are not very rigidly adhered to. In some ways the book resembles a series of problem-solving exercises. An initial chest radiograph is presented followed by the ever-present question as to what to do next. Thus it provides a painless method for the radiologist to revise his chest radiology, especially in the light of new techniques. It will be especially valuable for final F.R.C.R. candidates. Many clinicians will also find it useful. There is, of course, the temptation just to look at the 111 problems and skip the text, which is somewhat overpowered by the images. This would be a pity as the text contains many useful asides (Goddardisms) which give this book such a distinct character. In any case the whole book (cases plus text) can easily be read in a few hours.

So, there is much to credit. The only real criticism which can be levelled is that some of the images are not very clear. This is largely because the paper is so thin that many of the images are marred by those on text overleaf. A further problem is that the CT images are largely derived from an EMI 5005 machine. Thus there is only minor emphasis on intravenous contrast enhancement and magnification techniques, which can be very helpful for mediastinal and hilar problems. On the other side of the coin, the detail of pulmonary parenchymal conditions (*e.g.* emphysema) is remarkable; of course this is one of the author's particular interests.

Overall it is an impressive and unusual work. I suppose £45 is the going rate for such a book nowadays. I fear that many F.R.C.R. candidates will look at the library copy rather than buy their own.

ADRIAN DIXON

Magnetic Resonance of the Musculoskeletal System. Ed. by T. H. Berquist, R. L. Ehman and M. L. Richardson, pp. xiv+220, 1987 (Raven Press, New York), $32.40.
ISBN 0-88167-220-3

The first three chapters of this book are concerned with the basic principles and technical considerations of magnetic resonance imaging (MRI) and the remaining five chapters with magnetic resonance images in the various disease processes. I, along with many others, find understanding and retaining the physics of MRI extremely difficult and have relied heavily on the article by Smith in *Clinical Radiology* (1986). This book is equally good in explaining the basic concepts and is very effective in relating these to pathological processes and the production of the images. I found it valuable to refer to the first three chapters when reading those on the disease processes.

The first of the chapters on disease processes deals with tumours and in particular with soft-tissue lesions. The effectiveness of MRI in showing the extent of soft-tissue masses and their relationship to major vessels and nerves in the coronal, sagittal and transverse planes is covered well. Other chapters on infection, trauma, osteonecrosis and other conditions are adequately discussed.

Low back pain is such a common condition, it is surprising there is only a relatively short section on the degenerative conditions. We have found MRI of considerable value in assessing disc disease, particularly in being able to reduce the number of discograms done.

Overall, I consider this book to be well written and compiled and to contain much information. It is ideal for the radiologist who is interested in musculoskeletal radiology and wishes to know the present scope and possible utility of MRI.

B. J. PRESTON

Pediatric Imaging/Doppler Ultrasound of the Chest: Extracardiac Diagnosis. By James C. Huhta, pp. xiii+225, 1986 (Lea & Febiger, Philadelphia), $46.75.
ISBN 0-8121-1037-4

Although the use of two-dimensional and Doppler ultrasound techniques is well established in the elucidation of intracardiac pathology, their use elsewhere in the thorax is less well established. This is therefore a timely publication. The book is directed towards a wide spectrum of paediatricians, not only just cardiologists, like the author, but also physicians, surgeons and radiologists.

The initial chapters on the techniques of paediatric ultrasound examination and the cross-sectional ultrasound tomographic appraoch to intrathoracic pathology are simply, yet clearly, expounded. In addition to black and white scan images, a set of 29 colour plates is used to illustrate anatomy and transducer manipulation. In the review copy these colour plates seem to be rather aimlessly situated between later chapters on the pulmonary arteries and the pulmonary veins. As the plates do not share the ordinary page numeration they are not particularly well located; perhaps this was a binding error. The third chapter on Doppler assessment of blood flow will be found refreshingly simple by the average radiologist, whose grasp of physics is becoming rather rusty. The rest and major part of the book deals with the thoracic contents: thymus, trachea and oesophagus; ascending aorta; aortic arch, isthmus and descending aorta; ductus arteriosus; pulmonary arteries and veins; pleura, pericardium and diagragm; and finally extracardiac masses. Typically in each chapter an introduction considers the ultrasonic approach; then the normal morphology of the structures is described and illustrated by clear two-dimensional ultrasound scans. In particular, labelling of the pictures is clear and adequate. The various abnormalities and anomalies are then illustrated. This is supplemented from time to time with occasional angiograms or line drawings. Doppler images are incorporated as necessary. Each chapter has a section of current or relevant references.

This book should appeal to general and paediatric radiologists as the application of ultrasound inexorably increases. Enough intracardiac pathology is revealed to help understanding of extracardiac vascular problems. The aspiring dedicated cardiac ultrasonographer would find this a useful starting point.

D. G. SHAW

1987, *The British Journal of Radiology*, *60*, 957–968 OCTOBER 1987

Magnetic resonance imaging in the evaluation of nose and paranasal sinus disease

By *Glyn A. S. Lloyd, D.M., F.R.C.R., Valerie J. Lund, F.R.C.S., Peter D. Phelps, M.D., F.R.C.R., F.R.C.S. and David J. Howard, F.R.C.S.

Royal National Throat, Nose and Ear Hospital, Gray's Inn Road, London WC1X 8DA

(*Received October 1986 and in revised form December 1986*)

ABSTRACT

Fifty patients with a wide range of sinus disease have been examined by magnetic resonance. These included congenital conditions, inflammatory and allergic sinus disease, fungus infection, and both necrotising and non-necrotising granulomas. A variety of benign and malignant tumours have been investigated, including eight examples of juvenile angiofibroma and 19 malignant sinus tumours. This experience of magnetic resonance scanning has shown that it is superior to computed tomography in showing the extent of malignant disease and, provided the correct pulse sequences are employed, it is always possible to distinguish tumour from retained secretion or inflamed mucosa. The extent of intracranial invasion can also be optimally demonstrated. One of the advantages of the method is the direct three-plane imaging and multislice technique, which gives total coverage of the head and neck for the assessment of malignant disease. Tissue diagnosis in the paranasal sinuses is less important than the demonstration of tumour extent and distribution. Only one tumour (juvenile angiofibroma) showed diagnostic spin-sequence characteristics, and no differentiation was observed between malignant tumours of epithelial and mesenchymal origin. The major drawback of magnetic resonance is the poor demonstration of bone and calcification in the sinuses, so that in some patients the scans need to be augmented by computed tomography studies.

The introduction of nuclear magnetic resonance head scanning in Britain by Holland et al (1980), Hawkes et al (1980) and Doyle et al (1981) added a new modality for the demonstration of paranasal sinus disease. As in other areas of the head and neck, this technique has many advantages over established methods of investigation such as computed or multidirectional tomography. The purpose of this paper is to record the findings in 50 patients, displaying a wide spectrum of benign and malignant pathology encountered in the nose and paranasal sinuses, who have been investigated by this technique. The patients were selected with some emphasis on those conditions in which magnetic resonance scanning has proved particularly valuable, for example juvenile angiofibroma. The intention has been to evaluate the influence of this technique on patient management and to compare it with other methods of investigation such as computed tomography (CT) and conventional radiography.

CASE MATERIAL

Fifty-two patients were submitted for investigation by magnetic resonance. Two examinations were unsuccessful because the patients were claustrophobic. The remaining 50 had the following histologically proven conditions.

(1) Congenital abnormality (meningo-encephalocele) (one patient)
(2) Inflammatory and allergic disease (acute and chronic sinus infection, nasal polyposis, mucocele and pyocele formation) (10 patients)
(3) Fungus infection (aspergillosis) (one patient)
(4) Granulomas (Wegener's granuloma, midline lethal granuloma, giant-cell reparative and cholesterol granuloma) (five patients)
(5) Benign tumours (dermoid, fibro-osseous disease, inverted papilloma, meningioma and angiofibroma) (14 patients)
(6) Malignant tumours (tumours of epithelial origin including squamous-cell carcinoma, adenocarcinoma, adenoid cystic carcinoma, anaplastic carcinoma and olfactory neuroblastoma) (12 patients)
(7) Mesenchymal tumours (rhabdomyosarcoma, chondrosarcoma, osteosarcoma and lymphoma) (seven patients)

METHOD OF EXAMINATION

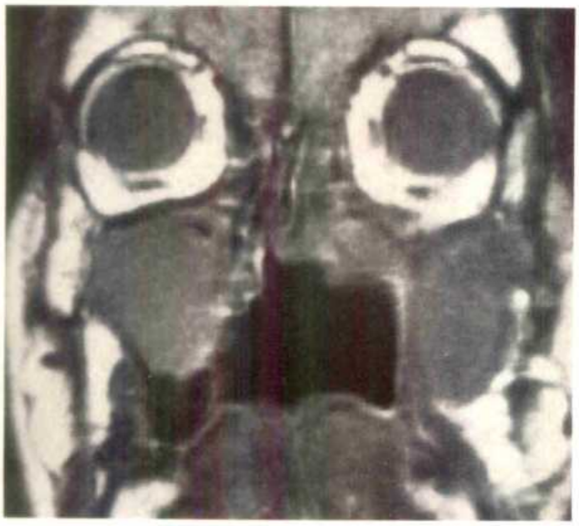
Two magnetic resonance scanners using superconducting magnets with medium (0.3 T) and high (1.5 T) static field strengths have been used for this investigation. Initially spin-echo sequences only were employed; latterly inversion-recovery sequences, in addition to T_1-weighted and T_2-weighted spin-echo sequences, have been added. All inversion-recovery sequences were made at an inversion time (TI) of 500 ms and a repetition time (TR) of 2100 ms. Spin-echo sequences were made with a time to echo (TE) varying between 30 ms and 90 ms and repetition times of 500–3000 ms. Routine three-plane imaging was employed using a multislice technique with contiguous sections up to 12 cm in the sagittal, axial and coronal planes and sections of 1 cm or 0.5 cm thickness.

TISSUE CHARACTERISTICS

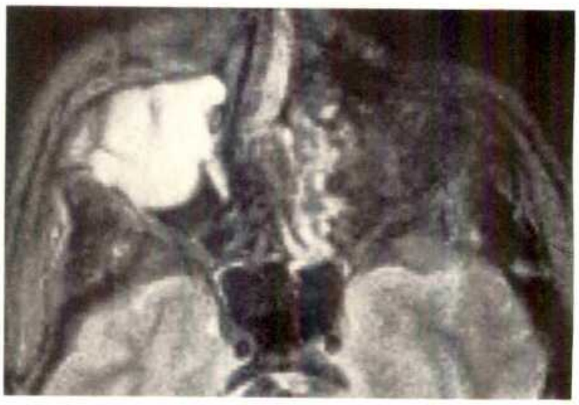
The spin characteristics on T_1- and T_2-weighted scans were evaluated for the lesions in this series.

---

*Author for correspondence and reprint requests.



A

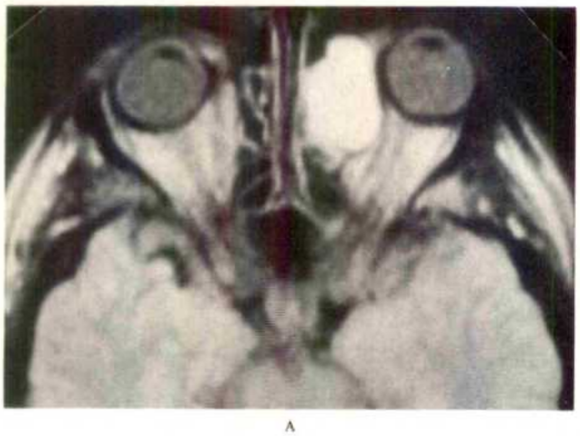


B

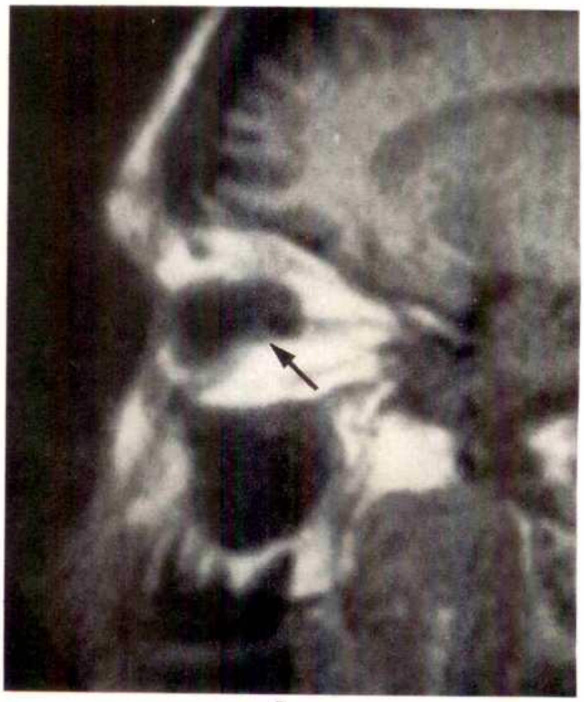
FIG. 1.

(A) SE700/30, coronal section. Recurrent osteosarcoma in the paranasal sinuses. The T_1-weighted scan shows no discrimination between tumour in the left antrum and inflammatory mucosa in the right. (B) SE3200/90, axial section. Heavily weighted T_2 sequence showing strong signal from inflamed mucosa in the right antrum, and a very low-intensity signal from the left antrum containing recurrent tumour.

Relative signal intensity of pathological and normal tissue was assessed for each sequence by using the grey scale as reference on both the inversion-recovery and spin-echo sequences. With the limited number of patients examined in each category it was only possible to make some preliminary observations concerning tissue specificity from the spin characteristics. Firstly, the angiofibromas were recognisable by their typical distribution and obvious vascularity (Lloyd & Phelps, 1986). In the malignant tumours, there was no significant difference in mean signal intensity between the tumours of epithelial and mesenchymal origin. In



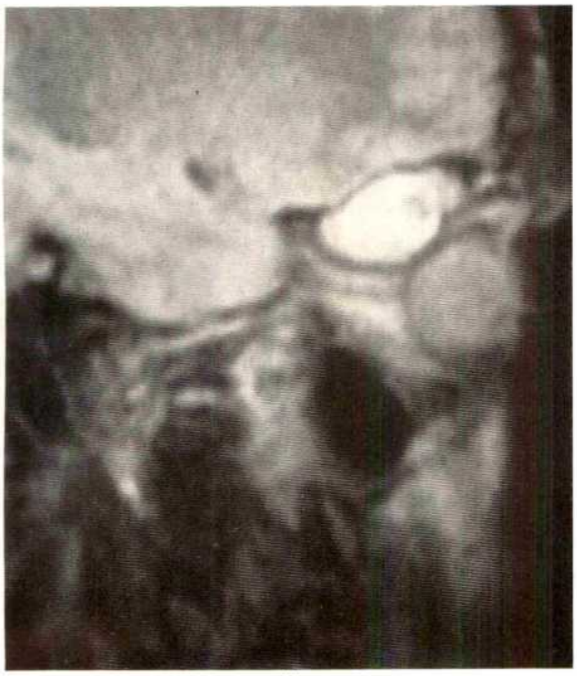
A



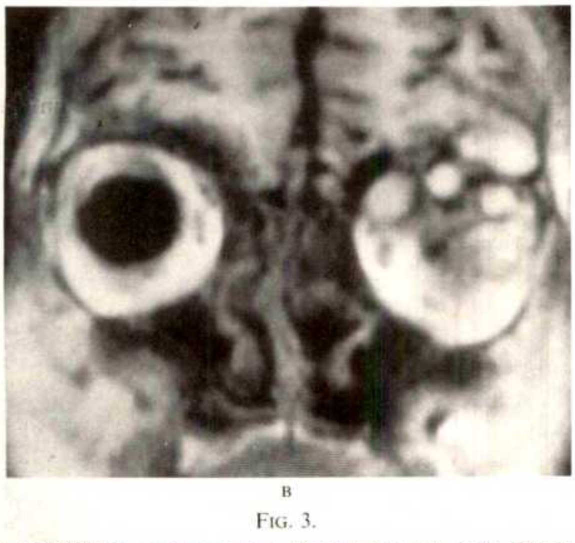
B

FIG. 2.

(A) SE1500/60, axial section showing an anterior ethmoid mucocele which gives a strong signal on the T_2-weighted sequence. (B) IR2100/500, sagittal section. On inversion recovery the mucocele (arrow) gives almost no signal.



A



B

FIG. 3.

(A) SE2000/80, sagittal section. Frontal sinus mucocele. Strong signal on T_2-weighted sequences. (B) IR2100/500, coronal section. On inversion recovery the anterior loculi of the mucocele still show strong signal, owing to the presence of blood breakdown products from previous surgical intervention.

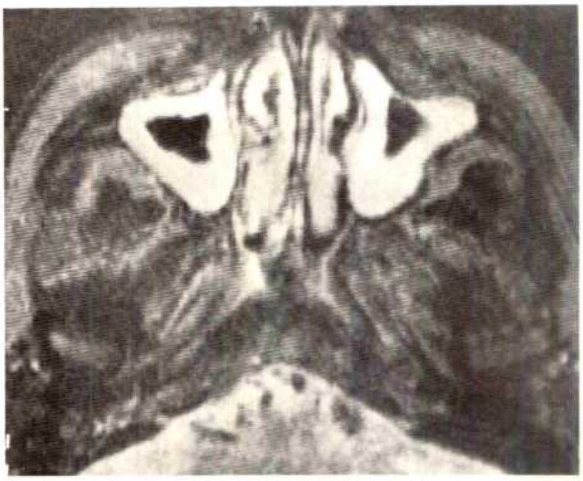


FIG. 4.

SE3200/90, axial section. T_2-weighted spin-echo sequence showing inflammatory mucosal thickening in the maxillary antra.

general, the malignant tumours produced signals of medium intensity on T_1-weighted spin-echo sequences with moderately strong signals on T_2 images. In contrast, retained secretion and mucocele formation produced high signals on spin-echo sequences, the differentiation being particularly striking on T_2-weighted images, the retained secretion always producing a stronger signal than tumour. An additional feature was the heterogeneous signal of tumour in comparison with that shown by retained secretion, which was invariably homogeneous. The vascularity of the tumour was a major contributor to the lack of homogeneous signal seen in the group of patients with angiofibromas. In these benign tumours, large vessels could be identified, both in the tumour itself and in the adjacent musculature.

The signal characteristics of normal nasal mucosa covering the turbinates was evaluated. Because of its highly vascular nature, nasal mucosa gives a signal similar to inflamed or oedematous sinus epithelium, *i.e.* a high-intensity signal on T_2-weighted spin-echo sequences, allowing discrimination between tumour and normal mucosa; on the other hand, when T_1-weighted sequences are used, the signal intensities are very similar and tumour differentiation is difficult. Inflamed or oedematous sinus mucosa also produces a signal of high intensity on T_2-weighted sequences and may be distinguished from tumour by this means. This distinction is especially apparent on heavily weighted T_2 sequences using a very long TE and a long TR (Fig. 1). This is a valuable feature of the technique, both for post-operative follow-up assessment of possible tumour recurrence and for monitoring the results of radiotherapy or chemotherapy. Polyps also produce a strong signal on spin-echo sequences, approaching that of retained secretion, so that differentiation between polyps and retained secretion may be very difficult (see Fig. 5).

The spin characteristics of the four mucoceles in the series varied with their surgical history, *i.e.* whether

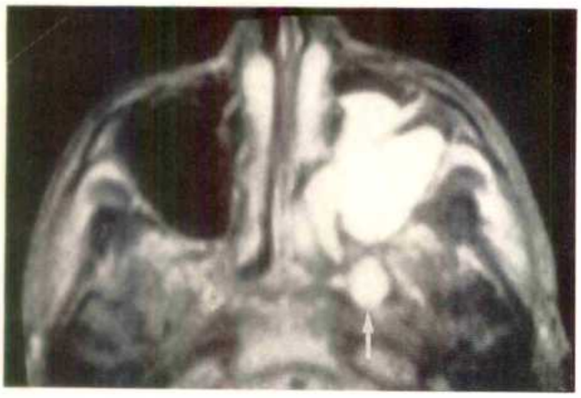


FIG. 5.

SE2000/80, axial section. Antro-choanal polyp. At surgery the anterior compartment of the antrum contained fluid which was indistinguishable on magnetic resonance from the polyp in the posterior part of the antrum. The polyp can be seen extending into the nasal cavity via the antral ostium, and its nasopharyngeal component can be seen posteriorly in the roof of the nasopharynx (arrow).

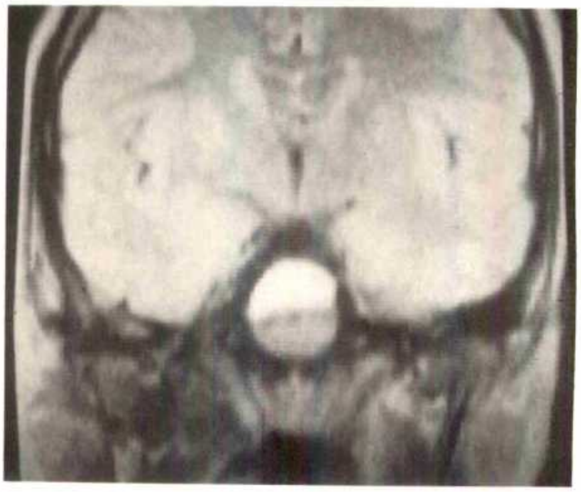


FIG. 6.

SE1500/60, coronal section. Dilated sphenoid sinus showing retained secretion superiorly and tumour (angiofibroma) inferiorly.

there had been previous surgical intervention or not. This is important because the presence of haematoma and altered blood affects the spin characteristics. This is thought to be due to the breakdown of red cells with the release of methaemoglobin, a paramagnetic agent (Gomori et al, 1985). An untouched mucocele will present a high signal on T_2-weighted spin-echo sequences and a very low signal on inversion recovery, because of its long T_1 (Fig. 2). In contradistinction, a frontal sinus mucocele in which there had been a previous attempt at drainage produced a signal of mixed intensity, some loculi of the mucocele producing high signal both on inversion-recovery and T_1- and T_2-weighted spin-echo sequences (Fig. 3). At surgery, a mixture of mucus and altered blood was drained from the sinus, suggesting that the signal characteristics were partially due to haematoma formation following the previous surgery.

DISCUSSION

Magnetic resonance scanning can show simple inflammatory or allergic changes in the sinuses. It is possible to show single or multiple polyps, thickened mucosa (Fig. 4), or fluid levels in the presence of infection. These conditions are generally well demonstrated by conventional radiography and the need to recognise them is simply to be able to distinguish them from more serious disease. An example of this is seen in Fig. 5, which shows an antro-choanal polyp in a 27-year-old man. This was diagnosed clinically as an angiofibroma but was clearly shown to be arising from the maxillary antrum and also gave the spin characteristics of an antro-choanal polyp (*vide infra*).

One of the advantages of magnetic resonance scanning is the strong signal which is received on T_2-weighted spin-echo images from retained mucus or muco-pus in the sinuses. This enables an important distinction to be made between tumour in the sinuses and retained secretion or secondary mucocele formation, even within the same sinus cavity (Fig. 6). In the same way, primary mucoceles or pyoceles are optimally demonstrated by this technique (see Fig. 2). Theoretically it should be possible to distinguish between cystic and solid masses in the sinuses on the evidence of the CT attenuation values: cystic lesions should show a low attenuation on the Hounsfield scale and should not enhance with intravenous contrast agents. In practice this distinction is not always easy to make: some solid tumour masses do not enhance after contrast on CT and some cystic masses show high

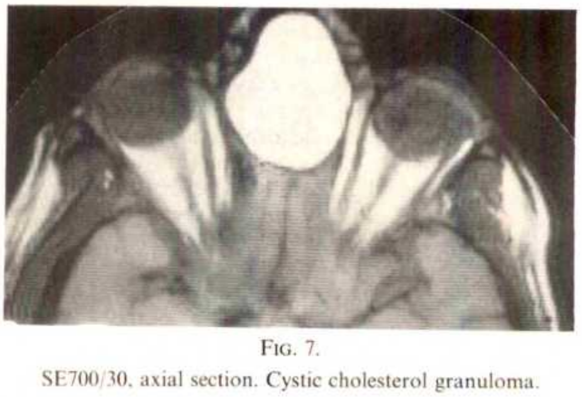


FIG. 7.

SE700/30, axial section. Cystic cholesterol granuloma.

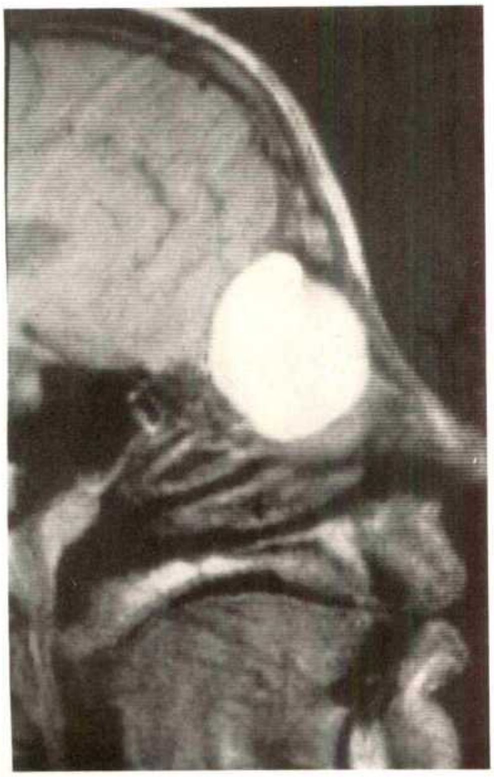


Fig. 8.

SE700/30, sagittal section. Same patient as in Fig. 7, showing hyperintense signal from the cholesterol granuloma.

attenuation. There is usually no difficulty in making this differentiation by nuclear magnetic resonance.

Figures 7 and 8 show the magnetic resonance scans of a 17-year-old man with a midline cystic cholesterol granuloma encroaching upon the nasal cavity and invading the anterior fossa through a midline defect in the ethmoid cells and cribriform plate. The evidence of plain radiograph and CT scan (Figs 9, 10) suggested that this was a solid mass and, therefore, an encephalocele or meningoencephalocele rather than a fluid-containing cavity as demonstrated by magnetic resonance and confirmed at surgery.

Cholesterol granuloma is a condition which normally occurs in the facial skeleton, either in the superotemporal quadrant of the orbit and adjacent frontal bone, or in the maxillary antrum (Lloyd, 1986). The aetiology is generally thought to be due to a previous haemorrhage with the breakdown of red blood cells to form cholesterol crystals which in turn provoke a granulomatous reaction (Hellquist et al, 1984). In the case described, the wall of the cyst contained cholesterol clefts and the fluid in the cyst was rich in cholesterol crystals, which may have been the cause of the strong signals received from spin-echo sequences on both T_1- and T_2-weighted images. A second possibility is that the presence of free methaemoglobin within the cyst, formed from the breakdown of red blood cells, acted as a paramagnetic contrast agent producing a hyperintense signal as described for intracranial haematomas (Gomori et al, 1985).

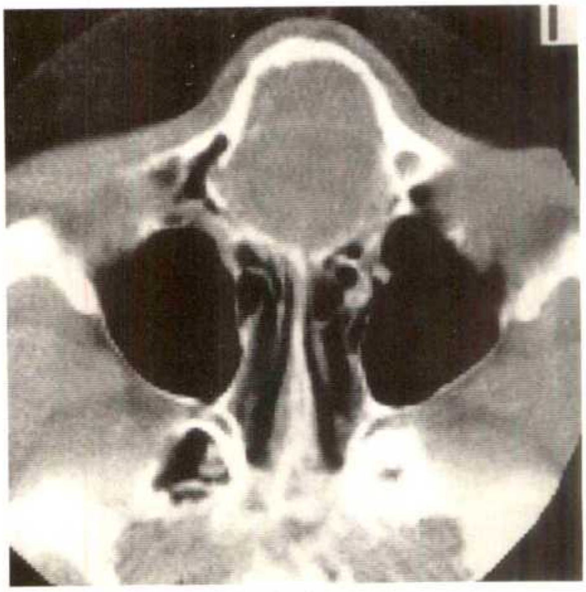


Fig. 9.

Same patient as in Figs 7 and 8. Axial CT (WL = 20, WW = 400) showing bone defect in the anterior ethmoids.

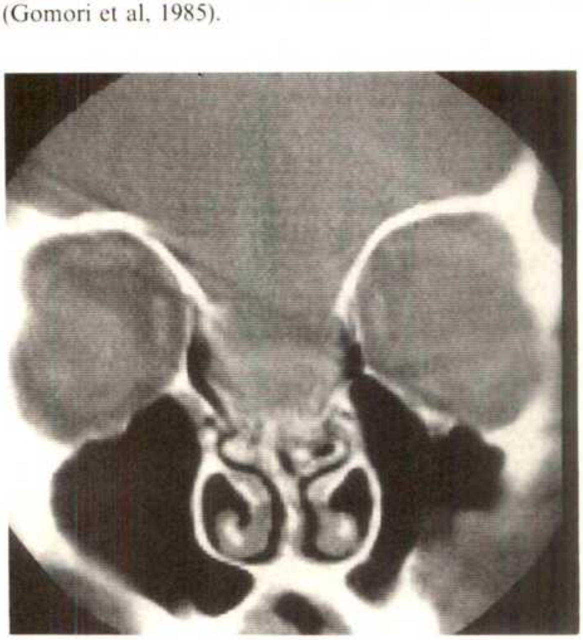
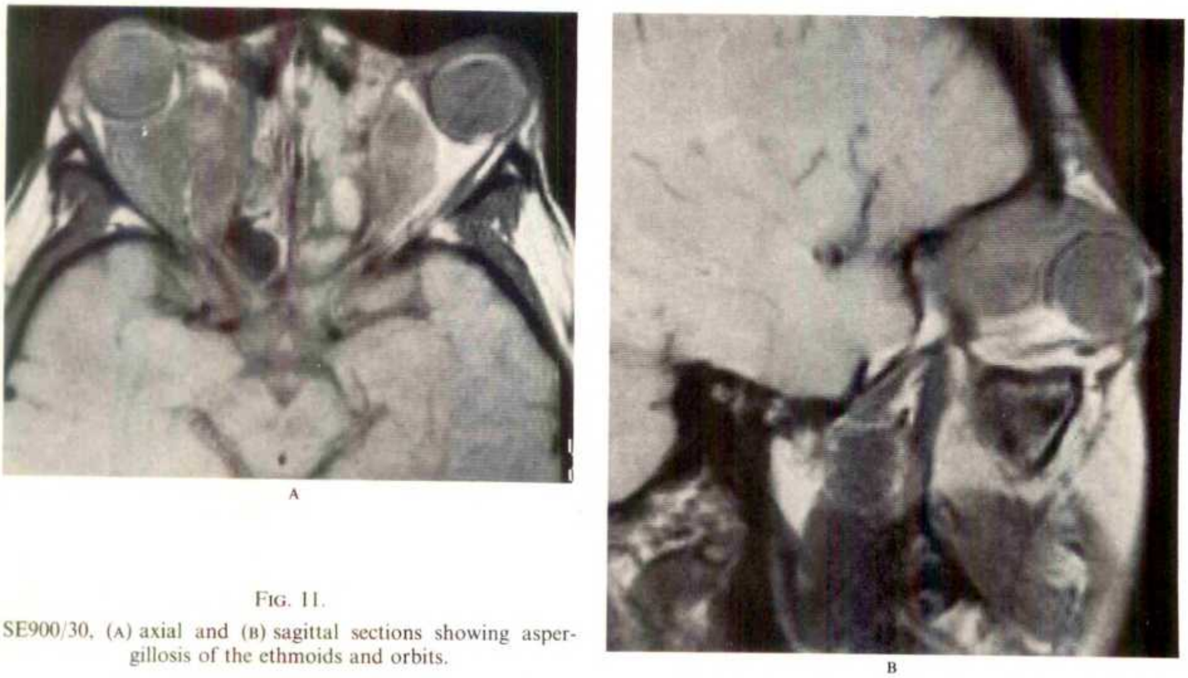


Fig. 10

Same patient as in Figs 7, 8 and 9. Coronal CT (WL = 20, WW = 400) showing defect in the floor of the anterior fossa.


A

B

FIG. 11.

SE900/30, (A) axial and (B) sagittal sections showing aspergillosis of the ethmoids and orbits.

Changes in the sinus mucosa also give a strong signal on T_2-weighted images. Simple mucosal thickening associated with infection is clearly outlined against the air space and small ethmoidal polyps or polypoid mucosal thickening in the maxillary sinus is easily recognised. Nasal polyps are oedematous, prolapsed mucosa of the ethmoidal cells, with a histological picture of respiratory epithelium covering a grossly oedematous stroma. The differentiation of retained secretion in the sinuses and nasal polyps is less easily made by magnetic resonance than the distinction between retained secretion and a true neoplasm, either benign or malignant. The close similarity of signal characteristics of an oedematous polyp and its associated mucosal secretion makes the differentiation difficult particularly on T_1-weighted images, but differentiation may be possible on T_2-weighted pulse sequences.

Aspergillus is a common saprophyte of soil, dust and decaying vegetable matter which may be pathogenic in man and animals. It gains access to the sinuses, bronchi and lung parenchyma via the nose. It may occur in an enfeebled host but also affects otherwise healthy individuals. Two forms of the condition are recognised: an invasive and a non-invasive form. The former acts like a malignant neoplasm in the sinuses with bone destruction, orbital involvement and occasional intracranial extension; the latter presents like a bacterial sinusitis, with rhinorrhoea, nasal congestion and an opaque antrum on plain radiographs. One example of the invasive form of this fungus infection has been investigated by magnetic resonance. The extent of the bilateral orbital involvement was best shown on T_2-weighted spin-echo sequences (Fig. 11).

Non-healing mid-facial granulomas of the nose are of two varieties: Wegener's granuloma and Stewart's midline lethal granuloma. Wegener's granuloma is a multisystem disease characterised by necrotising granulomas of the upper and lower respiratory tract associated with glomerulonephritis and a systemic vasculitis. Midline lethal granuloma is a localised disease process of the midface, with acute inflammatory

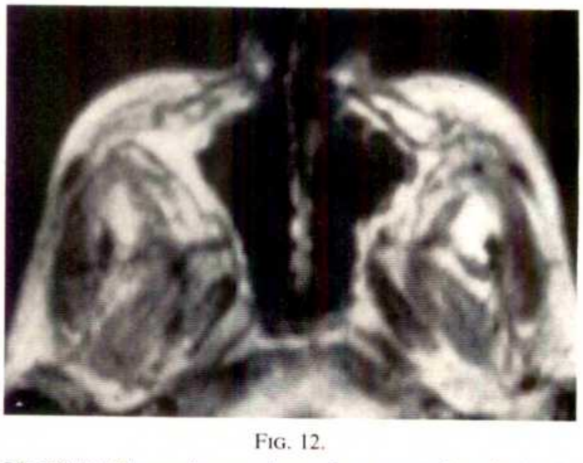


FIG. 12.

SE1500/80. Wegener's granuloma. Large central cavity in the nose and sinuses lined by inflammatory mucosa giving a strong signal on T_2-weighted sequences.

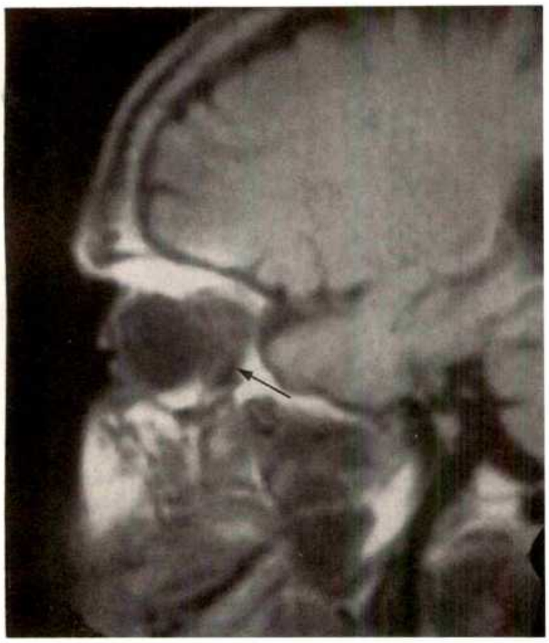


FIG. 13.

SE680/40. Same patient as in Fig. 12. Sagittal section showing dense fibrosis within the intraconal space (arrow) of the orbit.

changes, granuloma formation and tissue necrosis. The intense destruction of the upper airway seen in patients with this condition is rarely found in Wegener's granuloma, but the changes are similar radiologically and the difference is probably one only of degree. In the majority of patients, necrosis is halted in Wegener's granuloma either by successful therapy or by death before it has reached the stage of massive bone destruction seen in midline lethal granuloma; such changes are seen in Wegener's granuloma only in long-term survivors (*vide infra*). Characteristically there is no bulky soft-tissue mass accompanying the bone necrosis and this serves to distinguish these conditions from malignant nasal or sinus tumours. In a single example of a patient with lethal midline granuloma, magnetic resonance contributed little to the diagnosis, largely because of the absence of bone signal. This is a major drawback in the magnetic resonance demonstration of sinus pathology, and in this instance the diagnosis was made by high-resolution CT.

Two patients with Wegener's granuloma have been examined. The first is a long-term survivor, the diagnosis having been established for 16 years. The magnetic resonance scan was dominated by massive central bone necrosis in the nose and sinuses, interpretation being complicated by previous orbital decompression surgery. The resultant cavity was lined by granulations giving a strong signal on T_2-weighted sequences (Fig. 12). This patient also had massive infiltration of both orbits. At decompression this was shown to be due to dense fibrosis, the signal characteristics of which were quite different from those of the nose and sinus granulation tissue, giving a low signal on both T_1- and T_2-weighted spin-echo sequences (Fig. 13). The second patient with Wegener's granuloma produced exactly similar magnetic resonance changes, with high-intensity signals on T_2-weighted sequences from the granulations in the nose and sinuses, and a hypo-intense signal from the tissue infiltrating the left orbit on both spin-echo and inversion-recovery scans. This was presumably again due to the presence of dense fibrous tissue as opposed to the more active granulomatous process in the mucous membrane of the nose and paranasal sinuses.

Giant-cell reparative granuloma is a term first introduced by Jaffe (1953) to distinguish this non-neoplastic condition from true giant-cell tumours. In the craniofacial bones, the latter are extremely rare and the majority of giant-cell lesions belong to the reparative granuloma group. The condition occurs predominantly in the mandible but is also seen in the paranasal sinuses. It is a disease of the young, with peak incidence in the second decade. Radiographic features are non-specific: the granuloma may cause bone expansion, mimicking a benign tumour or mucocele, or cause bone destruction, like a malignant neoplasm. An example of giant-cell granuloma of the sphenoid has been investigated by magnetic resonance scanning in a 17-year-old girl who presented with epistaxis and nasal obstruction. The mass showed a strong signal on T_2-weighted spin-echo sequences, with a generalised expansion of the sphenoid sinus, involving the base of the pterygoid laminae, the planum sphenoidale and the clivus. The signal was stronger than that shown by most sinus tumours but less than that normally produced by retained secretion or mucocoele formation.

Fibro-osseous disease presents in the facial skeleton, as either the diffuse change seen in fibrous dysplasia or the more localised form of ossifying fibroma. In fibrous dysplasia, normal bone is replaced by cellular fibrous tissue and partly formed trabeculae of woven bone with an irregular pattern and distribution. Ossifying fibroma is probably a localised variety of this condition but differs in that there is lamellar bone and osteoid, which are not often found in active fibrous dysplasia. Ossifying fibroma is well demarcated from the surrounding normal bone and, unlike fibrous dysplasia, may continue to enlarge after cessation of skeletal growth. Two examples of ossifying fibroma have been examined. On plain radiographs or CT these lesions typically show either a homogeneous "ground-glass" appearance throughout or a less dense image containing scattered and irregular areas of calcification. The two cases scanned were of the latter variety. Both produced a strong signal on T_2-weighted sequences and both showed areas of signal void, corresponding to calcification shown on conventional radiography or CT scan (Figs 14, 15).

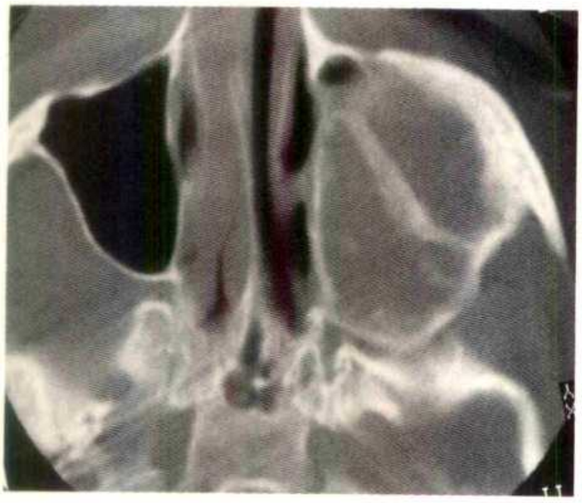


FIG. 14.
Axial CT scan (WL = 240, WW = 4000) showing expansion of the left antrum due to an ossifying fibroma.

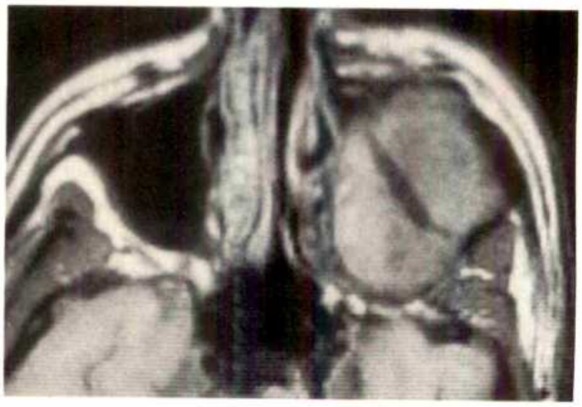


FIG. 15.
SE700/30. Same patient as in Fig. 14. Axial magnetic resonance scan. The diagonal bar of calcification is shown as an area of signal void.

Two recurrent primary extradural meningiomas in the sinuses have been examined. Failure to demonstrate hyperostosis and calcification is a drawback of magnetic resonance and in this case the technique was of less diagnostic value than CT. One patient showed a low-intensity rim (Fig. 16), a sign which has been described for intracranial meningiomas (Zimmerman et al, 1985; Mawhinney et al, 1986).

The largest group of any single tumour examined was the juvenile angiofibromas (eight patients). This tumour is unique in that it is the only neoplasm in the sinuses in which the radiologist may be called upon to make the initial diagnosis. Surgeons are reluctant to biopsy a fleshy nasopharyngeal mass in an adolescent male patient because of the danger of haemorrhage from this highly vascular tumour, relying upon clinical and radiological features to distinguish between an angiofibroma and a non-vascular lesion such as an antro-choanal polyp. On plain radiographs, the recognition of an angiofibroma is based on the "antral sign" described by Holman and Miller (1965). This is not always positive, however, and may be found with other tumours in the infratemporal fossa. The demonstration of enlargement of the sphenopalatine foramen and erosion of the base of the medial pterygoid plate on conventional or computed tomography is also diagnostic (Lloyd & Phelps, 1986). Magnetic resonance is now an alternative method of making the distinction between angiofibroma and antro-choanal polyp: the latter can be shown to arise within the maxillary antrum (Fig. 5), whereas angiofibromas take origin behind the maxillary sinus in the sphenopalatine foramen and pterygopalatine fossa. The spin characteristics are also different: an antro-choanal polyp produces a homogeneous signal of high intensity on T_2-weighted spin-echo sequences, while angiofibroma gives a heterogeneous signal due to areas of vascular signal void (Fig. 17).

The next task of the radiologist is to define the limits of the tumour prior to surgery, since this may influence the surgical approach. Most important in this respect is the demonstration of the extent of lateral spread into the infratemporal fossa. A more radical approach may be indicated in these circumstances rather than the usual lateral rhinotomy. The extent of the tumour and the degree of involvement of the infratemporal fossa may be demonstrated by an enhanced CT scan in the immediate post-injection phase, but this is now better achieved by magnetic resonance, which has several advantages. It better demonstrates the extent of the

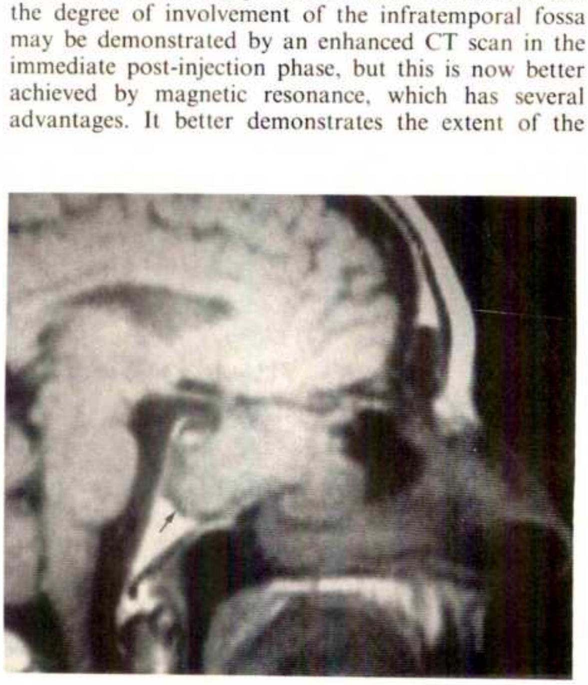


FIG. 16.
SE500/40. Recurrent meningioma in the nose and sphenoid sinus. The tumour shows a hypointense border (arrow).

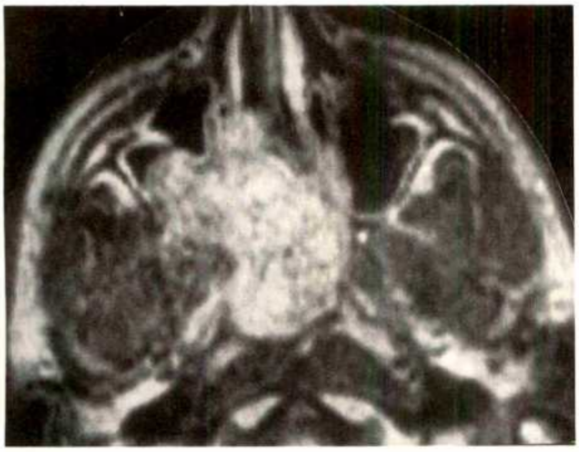


Fig. 17.

SE1500/60. Axial scan showing the vascularity in a juvenile angiofibroma. The vessels are shown as dark areas of negative signal.

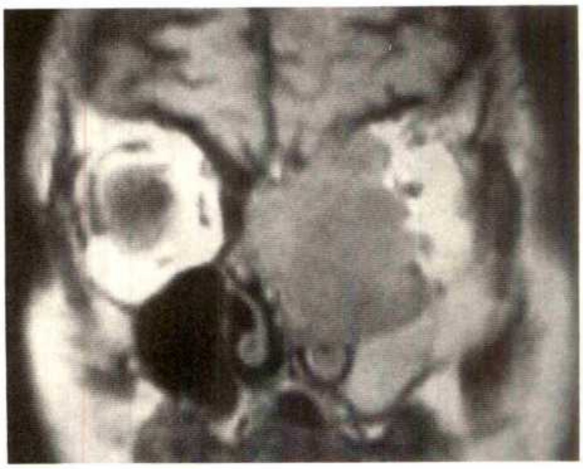


Fig. 18

SE560/40. Coronal section showing an adenocarcinoma with early invasion of the cribriform-plate area.

tumour than other modalities such as CT, and in this respect three-plane imaging with direct sagittal sections is an advantage. The vascular nature of angiofibroma is also clearly revealed by magnetic resonance (Fig. 17). Finally, all this is achieved without the use of ionising radiation or intravenous contrast agents.

The most important aspect of this study has been the application of magnetic resonance scanning to the management of malignant sinus disease. Virtually all malignant sinus tumours are diagnosed by biopsy and the various radiological and imaging techniques are needed, not for diagnosis, but to show the extent and distribution of the disease, which varies with different tumours. Adenocarcinoma and olfactory neuroblastoma are found principally in the nasal cavity and ethmoid labyrinth; squamous-cell carcinoma is usually antro-ethmoidal in location, whereas adenoid cystic carcinoma often arises in relation to the hard palate in the lower nasal cavity and maxillary antrum. Tumours arising in the ethmoid labyrinth, or extending into it, are liable to invade the anterior fossa via the frontal sinus or cribriform plate; in the case of adenocarcinoma (Fig. 18) or olfactory neuroblastoma (Fig. 19) this is likely to occur *ab initio*. In these circumstances radical craniofacial surgery to excise the malignancy is indicated (Cheesman et al, 1986). Pre-operative radiological assessment of anterior cranial fossa involvement will influence the size of the frontal craniotomy. Before the introduction of magnetic resonance the method of investigation employed has been to give a bolus of contrast agent immediately before a series of CT coronal sections (Lund et al, 1983). Magnetic resonance scanning can now replace this technique and with the addition of direct sagittal sections can give more exact information about the extent of anterior fossa invasion (Fig. 19).

The most emphatic demonstration of tumour above the cribriform plate was shown in a patient with an olfactory neuroblastoma who received a paramagnetic contrast agent (gadolinium DTPA) prior to scanning. This caused a strongly enhanced signal on inversion-recovery sequences, with clear demarcation of the tumour against normal brain tissue. The normal nasal mucosa also enhances strongly with this contrast agent (Carr & Gadian, 1985) so that in the nose and paranasal sinuses, discrimination between tumour and nasal mucosa becomes very difficult resulting, in this instance, in an overestimate of tumour size. However, despite this drawback, when paramagnetic contrast

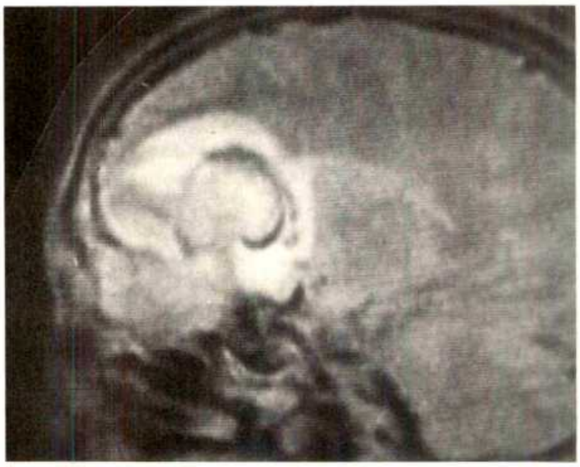


Fig. 19.

SE200/80. Sagittal section showing massive invasion of the anterior fossa by an olfactory neuroblastoma.

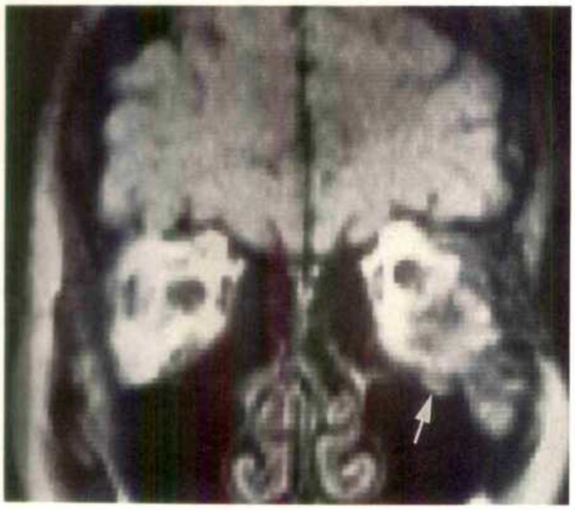


FIG. 20.

SE500/40. Coronal section showing a recurrent adenoid cystic carcinoma of the lacrimal gland. The tumour has invaded the maxillary antrum and has enlarged the infraorbital nerve and canal (arrow).

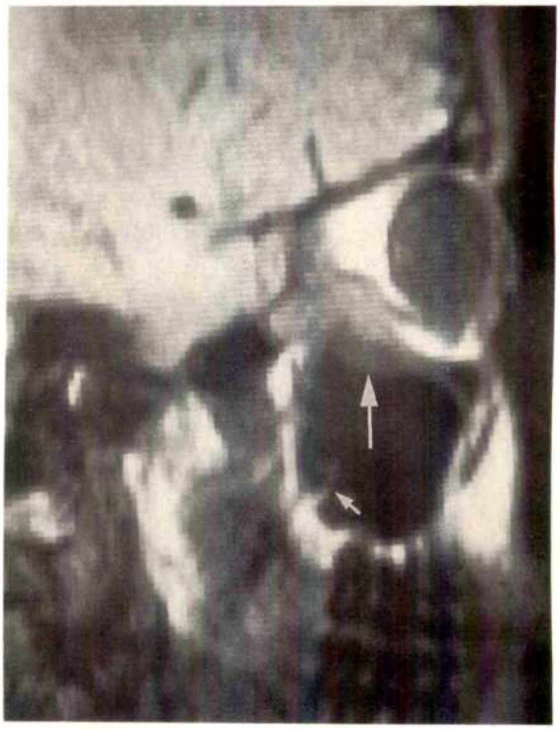


FIG. 21.

SE540/40. Same patient as Fig. 20. The sagittal section shows perineural infiltration of the infraorbital nerve by the adenoid cystic carcinoma (large arrow). The posterior superior dental nerve was also affected (small arrow). At surgery the whole of the second division of the fifth nerve was infiltrated by tumour back to the foramen rotundum.

agents become generally available, this will almost certainly become the method of choice for demonstrating intracranial extension.

Adenoid cystic carcinoma has a different distribution from the other malignant epithelial tumours in the nose and sinuses; many of these tumours take origin from ectopic salivary-gland tissue in the inferior nasal cavity and antrum. The hard palate is often involved initially and the tumour may spread through tissue planes rather than forming bulky masses. Adenoid cystic carcinoma, irrespective of its site of origin, is also capable of spreading by perineural lymphatic infiltration. Figure 20 is a magnetic resonance coronal section showing recurrent adenoid cystic carcinoma of the lacrimal gland on the floor of the orbit, with associated invasion of the maxillary antrum and enlargement of the infraorbital nerve. The latter was shown on sagittal section (Fig. 21), which also revealed thickening of the posterior superior dental nerve. The patient had experienced some tingling and abnormal sensation in the upper molar teeth on the side of the lesion and at surgery the whole of the second division of the fifth nerve was affected by perineural infiltration back to the foramen rotundum.

Seven patients with sarcomatous tumours have been examined by magnetic resonance scanning. Chondrosarcomas did not have any distinctive features, principally because of the lack of signal from calcified flecks and nodules that are normally associated with this tumour when demonstrated on either plain radiographs or CT. However, the technique is superior to other imaging methods in showing the extent of the tumour pre-operatively and distinguishing between tumour and retained sinus secretions.

In the paranasal sinuses, rhabdomyosarcoma is predominantly a tumour of the adolescent and young adult. At presentation, the tumour is usually well advanced, with a bulky mass occupying the nose, maxillary antrum and ethmoids. Spread to the sphenoid sinus and skull base may give rise to cranial nerve palsies and the tumour may invade the neck directly via the nasopharynx and parapharyngeal space or by lymph-node metastases. The high incidence of neck involvement by this tumour is well recognised (Fu & Perzin, 1976), in contrast to patients with malignant epithelial tumours in whom neck metastases are unusual (Lund, 1983). This was reflected in the three cases investigated in this series in which two had cervical involvement. One of these had a direct extension of the tumour from the maxillary antrum and pterygopalatine fossa to the parapharyngeal region, which was only recognised on the magnetic resonance scans (Fig. 22). This was the result of the wide coverage achieved by three-plane multislice imaging using a head

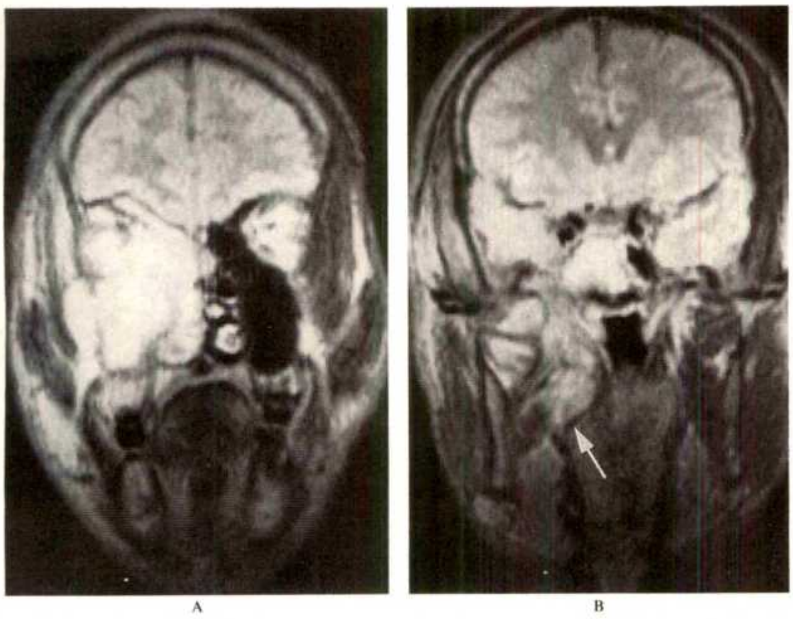


FIG. 22.

(A) SE1500/60. Coronal section showing a massive rhabdomyosarcoma of the nose and right maxilla. (B) SE1500/60. A more posterior coronal section shows a parapharyngeal extension of the rhabdomyosarcoma (arrow).

coil, which allows total scanning of the head and neck. This is a major advantage of the method and, in this respect, has revolutionised imaging of head and neck tumours.

The single example of an osteosarcoma in the series was a post-operative scan performed to show the extent of recurrence. Subsequent biopsy from the nasal cavity and sinuses showed good histological correlation of the recurrence sites shown on the spin-echo sequences using long TE sequences (Fig. 1).

CONCLUSION

This experience of magnetic resonance scanning has shown that it is superior to CT in demonstrating the extent of malignant disease in the paranasal sinuses. Provided the correct pulse sequences are employed, it should always be possible to distinguish tumour from retained secretion or inflamed sinus mucosa. The latter distinction is important when monitoring the effects of treatment and showing the presence of recurrent tumour. The extent of intracranial invasion can also be better demonstrated with or without the use of a contrast agent (gadolinium DTPA). In this respect one of the great advantages of the method is the direct three-plane imaging and multislice technique which, with the use of a head coil, gives total coverage of the head and neck in the assessment of malignant disease.

It is rare for any tumour in the paranasal sinuses to be inaccessible to biopsy, so tissue diagnosis by magnetic resonance is less important than the demonstration of tumour extent and distribution. Only one tumour, juvenile angiofibroma, could be recognised on the basis of its situation and spin characteristics. Other individual tumours were not examined in sufficient numbers to assess the possibility of tissue recognition, but no difference in spin characteristics was observed when the malignant epithelial tumours were compared with those of mesenchymal origin. At the present stage of development of the technique, full tissue recognition of sinus disease seems unlikely but, for the reasons stated above, such recognition would be of little practical advantage in the management of these patients. The important result of this investigation is that the technique has proved itself to be the best method of determining the extent of malignant sinus disease before and after surgery and for monitoring the effects of radiotherapy and chemotherapy.

The one drawback of magnetic resonance imaging has been the poor demonstration of bone and calcification in the sinuses. In some patients the magnetic resonance studies need to be augmented by high-resolution CT performed specifically to show bone detail.

ACKNOWLEDGMENT

Our thanks are due to Mrs N. Martin and Mrs E. Scrase and to the staff at the Queen Square Imaging Centre and Churchill Hospital for the magnetic resonance scans.

REFERENCES

CARR, D. M. & GADIAN, D. G., 1985. Contrast agents in magnetic resonance imaging. *Clinical Radiology*, *36*, 561–568.

CHEESMAN, A. D., LUND, V. J. & HOWARD, D. J., 1986. Cranio-facial resection for tumours of the nose and paranasal sinuses. *Head and Neck Surgery*, *8*, 429–435.

DOYLE, F. H., PENNOCK, J. M., ORR, J. S., GORE, J. C., BYDDER, G. M. & STEINER, R. E., 1981. Imaging of the brain by nuclear magnetic resonance. *Lancet*, *ii*, 53–57.

P25848

FU, Y. & PERZIN, K. H., 1976. Non-epithelial tumours of the nasal cavity, paranasal sinuses and nasopharynx: V skeletal muscle tumours (rhabdomyoma and rhabdomyosarcoma). *Cancer, 37,* 364–376.

GOMORI, J. M., GROSSMAN, R. I., GOLDBERG, H. I., ZIMMERMAN, R. A. & BILANIUK, L. T., 1985. Intracranial hematomas: imaging by high-field MR. *Radiology, 157,* 87–93.

HAWKES, R. C., HOLLAND, G. H., MOORE, W. S. & WORTHINGTON, B. S., 1980. Nuclear magnetic resonance (NMR) tomography of the brain: a preliminary clinical assessment with demonstration of pathology. *Journal of Computer Assisted Tomography, 4,* 577–586.

HELLQUIST, H., LUNDGREN, J. & OLOFSSON, J., 1984. Cholesterol granuloma of the maxillary and frontal sinuses. *Otorhinolaryngology, 46,* 153–158.

HOLLAND, G. M., HAWKES, R. C. & MOORE, W. S., 1980. Nuclear magnetic resonance (NMR) tomography of the brain: coronal and sagittal sections. *Journal of Computer Assisted Tomography, 4,* 429–433.

HOLMAN, C. B. & MILLER, W. E., 1965. Juvenile nasopharyngeal fibroma. *American Journal of Roentgenology, 94,* 292–298.

JAFFE, M. L., 1953. Giant cell reparative granuloma, traumatic bone cyst and fibrous (fibro-osseous) dysplasia of the jaw bones. *Oral Surgery, Oral Medicine and Oral Pathology, 6,* 159–175.

LLOYD, G. A. S., 1986. Cholesterol granuloma of the facial skeleton. *British Journal of Radiology, 59,* 481–485.

LLOYD, G. A. S. & PHELPS, P. D., 1986. Juvenile angiofibroma: imaging by magnetic resonance, CT and conventional techniques. *Clinical Otolaryngology, 11,* 247–259.

LUND, V. J., 1983. Tumours of the nasal cavity and paranasal sinuses. *Otorhinolaryngology, 45,* 1–12.

LUND, V. J., HOWARD, D. J. & LLOYD, G. A. S., 1983. CT evaluation of paranasal sinus tumours for craniofacial resection. *British Journal of Radiology, 56,* 439–446.

MAWHINNEY, R. R., BUCKLEY, J. M. & WORTHINGTON, B. S., 1986. Magnetic resonance imaging of the cerebello-pontine angle. *British Journal of Radiology, 59,* 961–969.

ZIMMERMAN, R. D., FLEMING, C. A., SAINT-LOUIS, L. A., LEE, B. C. P., MANNING, J. J. & DECK, M. D. F., 1985. Magnetic resonance imaging of meningiomas. *American Journal of Neuroradiology, 6,* 149–157.

1987, *The British Journal of Radiology*, 60, 969–974

A comparison of angiographic and electrocardiographically gated computed tomographic measurements of left-ventricular function

By C. J. Foster, M.R.C.P., W. C. Brownlee, M.R.C.P., *†J. F. Griffin, F.F.R.R.C.S.I., *J. Yates, H. G. Love, M.R.C.P. and *I. Isherwood, M.D., F.R.C.P., F.R.C.R.

Department of Cardiology, Manchester Royal Infirmary, and *Department of Diagnostic Radiology, University of Manchester, Manchester

(*Received January 1987*)

ABSTRACT

Fifty patients with ischaemic heart disease have been studied by electrocardiographically gated computed tomography (CT) and left-ventricular angiography to assess the accuracy of the former in the measurement of left-ventricular volumes and ejection fraction. There was no significant difference in the measurements of end-diastolic volume ($p = 0.9$, $r = 0.81$). Computed tomography significantly overestimated end-systolic volume ($p < 0.001$, $r = 0.89$) and significantly underestimated ejection fraction ($p < 0.001$, $r = 0.74$). Although there is some variation between the two sets of measurements, the correlation between the two techniques is good, indicating that electrocardiographically gated CT could be a useful non-invasive technique for assessing left-ventricular function.

The standard method for assessing left-ventricular function is left-ventricular angiography, which provides data on left-ventricular dimensions, volumes and ejection fraction. In addition, there is the advantage that pressure data can be obtained. As it is not always possible or justifiable to perform left-ventricular angiography, non-invasive techniques for the assessment of left-ventricular function have to be used in many cases.

Electrocardiographically gated computed tomography (CT) has been proposed as a non-invasive method for evaluating left-ventricular function (Brundage & Lipton, 1982). Previous studies using the technique in both animals and man have shown that it is possible to identify changes in left-ventricular dimensions at a single transverse section of the left ventricle following acute intervention and also to identify areas of abnormal wall motion (Mancini et al, 1983; Mattrey et al, 1983).

Theoretically, electrocardiographically gated CT has two major advantages over most other conventional techniques available for assessing left-ventricular function. Calibration is inherent in the technique and therefore calibration markers and correction formulae are not required. More importantly, computed tomographic measurements can be made directly from multiple transverse slices of the ventricle to obtain volumes without the use of formulae which assume the ventricle to be of a geometric shape.

One of the earliest reports of electrocardiographically gated CT stated that it should be possible to measure cardiac-chamber volumes (Sagel et al, 1977). The present study has been performed to confirm that this technique can provide accurate data on left-ventricular volumes and ejection fraction.

PATIENTS AND METHODS

Fifty patients with ischaemic heart disease were studied by both left-ventricular angiography and CT. The two studies were performed within a 6-month period, the majority of these (38) within 1 month. There were no prolonged episodes of chest pain, electrocardiographic changes or changes in medical treatment in the intervening period in any patients. Left-ventricular angiography was being performed in all patients as part of a diagnostic study.

Left-ventricular angiography

Left-ventricular angiograms at 50 frames/s were performed in the 40° right anterior oblique projection in all cases, with calibration markers being used. Left-ventricular volumes were calculated using Kennedy's modification of the area length method of Dodge for single-plane angiography (Kennedy et al, 1970). All measurements were corrected for magnification using the formula developed by Yang et al (1978). From these measurements the ejection fraction was calculated.

Computed tomography

The computed tomographic studies were performed using an IGE CT/T 8800 scanner modified to allow retrospective electrocardiographic gating to be performed. The scanner has a scan time of 5.6 s and an interscan time of 1.4 s. A scanned projection radiograph and four ungated scans (two at the base and two at the apex of the left ventricle) were performed to identify the

---

Author for correspondence: Dr C. J. Foster, Department of Cardiology, Manchester Royal Infirmary, Oxford Road, Manchester M13 9WL. Tel. 061 276 1234.

†Present address: Department of Diagnostic Radiology, St Vincent's Hospital, Dublin.

levels to be studied during contrast infusion. Scans of 1 cm thickness at 1 cm intervals were performed during intravenous infusion of contrast medium to encompass the whole of the left ventricle (four to six levels).

In order to provide adequate data to reconstruct gated images, five scans were performed at each level studied and the radiographic data stored in conjunction with the electrocardiographic data.

Intravenous contrast medium (Hexabrix or Conray 280; May & Baker Ltd) was injected into an antecubital vein using a Medrad Mark 4 power injector. This was commenced 1 min prior to the start of scanning; initially, a bolus of 25 ml at 10 ml/s was given and this was followed by an infusion at 10 ml/min which was continued until scanning was completed. All scans were performed during held maximum inspiration. Depending on the number of levels scanned (four to six), the total time for the examination was 4.5–6 min, the total dose of contrast medium being 70–100 ml.

An end-diastolic and an end-systolic image were reconstructed at each level scanned (Fig. 1) using the R-wave of the electrocardiogram as a reference point. Radiographic data obtained at specific points of the cardiac cycle were extracted from all five scans and used to reconstruct the gated image. The "gating window" (that time of the cardiac cycle during which data are extracted) available from the computer software is 100 ms. End-diastole was identified as occurring at the R-wave of the electrocardiogram. The timing of end-systole was established by reconstructing images at 35%, 40% and 45% of the R–R interval in 10 patients. In all 10, left-ventricular dimensions were significantly smaller at the 40% position (Foster, 1987). This timing was therefore used throughout the study.

End-diastolic and end-systolic volumes were measured by manually tracing round the left-ventricular endocardial border with a tracker ball and using conventional computer software to calculate the area within the region of interest (Fig. 2). This was performed at all the levels studied and the results summed. As each scan is of 1 cm thickness the volume is known. From these measurements the ejection fraction was calculated.

The measurements made from the two techniques were compared and, in addition, in those patients where heart rates had been recorded this was also compared. Statistical analysis was performed using Student's *t*-test.

Results

It was possible to measure the left-ventricular volumes from all of the ventricular angiograms. At CT it was not possible to measure the left-ventricular end-diastolic and end-systolic volume in three cases due to image artefact.

Left-ventricular volumes and ejection fraction

There was no significant difference between the angiographic and computed tomographic measurement of end-diastolic volume ($p = 0.9$). Comparison of the two techniques gave a coefficient of correlation of 0.81. Computed tomography significantly overestimated the end-systolic volume ($p<0.001$). The coefficient of correlation was 0.89. Computed tomography significantly underestimated the ejection fraction ($p<0.001$). The coefficient of correlation was 0.74 (Fig. 3).

Heart rate

The heart rate was recorded during left-ventricular angiography in all patients and in 30 of the 50 computed tomographic studies. There was no significant difference in heart rate between the two studies ($p = 0.52$). The coefficient of correlation was 0.51.

Discussion

Left-ventricular angiography is the accepted technique for assessing left-ventricular function. It does, however, have some major disadvantages.

1 It is highly invasive and its application is therefore limited.
2 Data on left-ventricular wall motion are only available from one or two projections.
3 Volume measurements are based on formulae which assume the ventricle to be of a geometric shape. This may be the case in the normal left ventricle (Dodge et al, 1960); however, where ventricular wall motion is abnormal these formulae will no longer apply.

Non-invasive techniques available for the study of left-ventricular function, though applicable to a larger population, also have their limitations. Echocardiography is an accurate method for measuring the left-ventricular short axis (Gibson, 1973). With both M-mode and cross-sectional echocardiography, however, as with angiography, calculation of volume is based on formulae which are dependent on the ventricle being a geometric shape. A further problem with echocardiography is the number of patients in whom it is not possible to obtain a completely adequate study because of adverse factors (Feigenbaum, 1981).

Radionuclide angiography is a potentially accurate method for measuring ejection fraction (Bodenheimer et al, 1980). This accuracy is, however, dependent on patient positioning and recognition of the possibility of superimposition of cardiac chambers. Although a qualitative impression can be gained regarding left-ventricular dimensions, it is difficult to calibrate radionuclide angiography and direct measurements are therefore not usually made.

Digital vascular imaging, by employing subtraction techniques, allows intravenous injection of contrast for left heart or arterial studies. The technique can provide information which is comparable to that obtained from left-ventricular angiography (Kronenberg et al, 1983). Where left-ventricular function is poor, however, the use of peripheral intravenous injection of contrast medium does not provide useful data because of prolonged pulmonary transit times and excessive

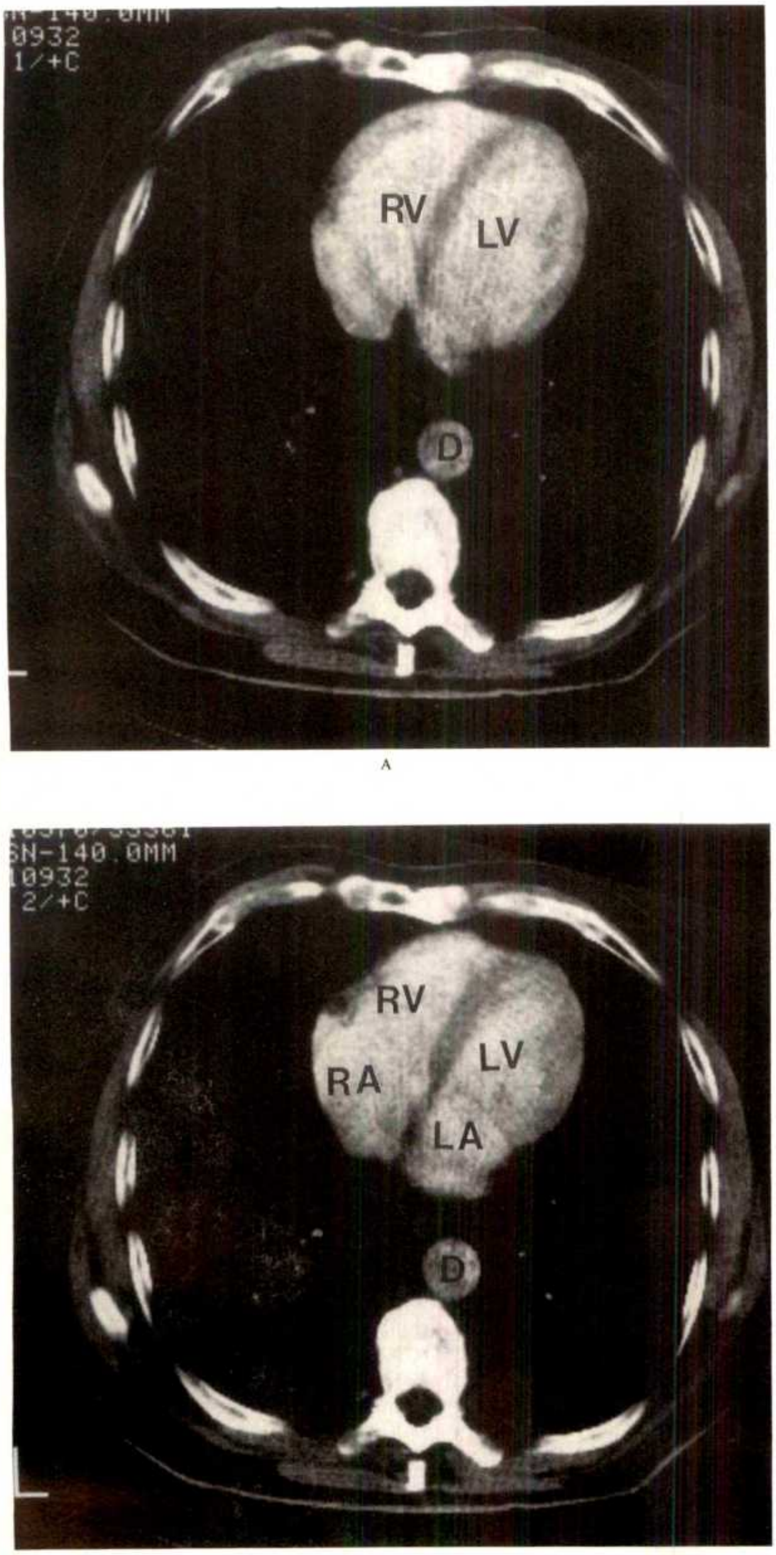


FIG. 1.

Electrocardiographically gated reconstructed images of the heart: (A) end-diastole, (B) end-systole. LV = left ventricle, RV = right ventricle, LA = left atrium, RA = right atrium, D = descending aorta.

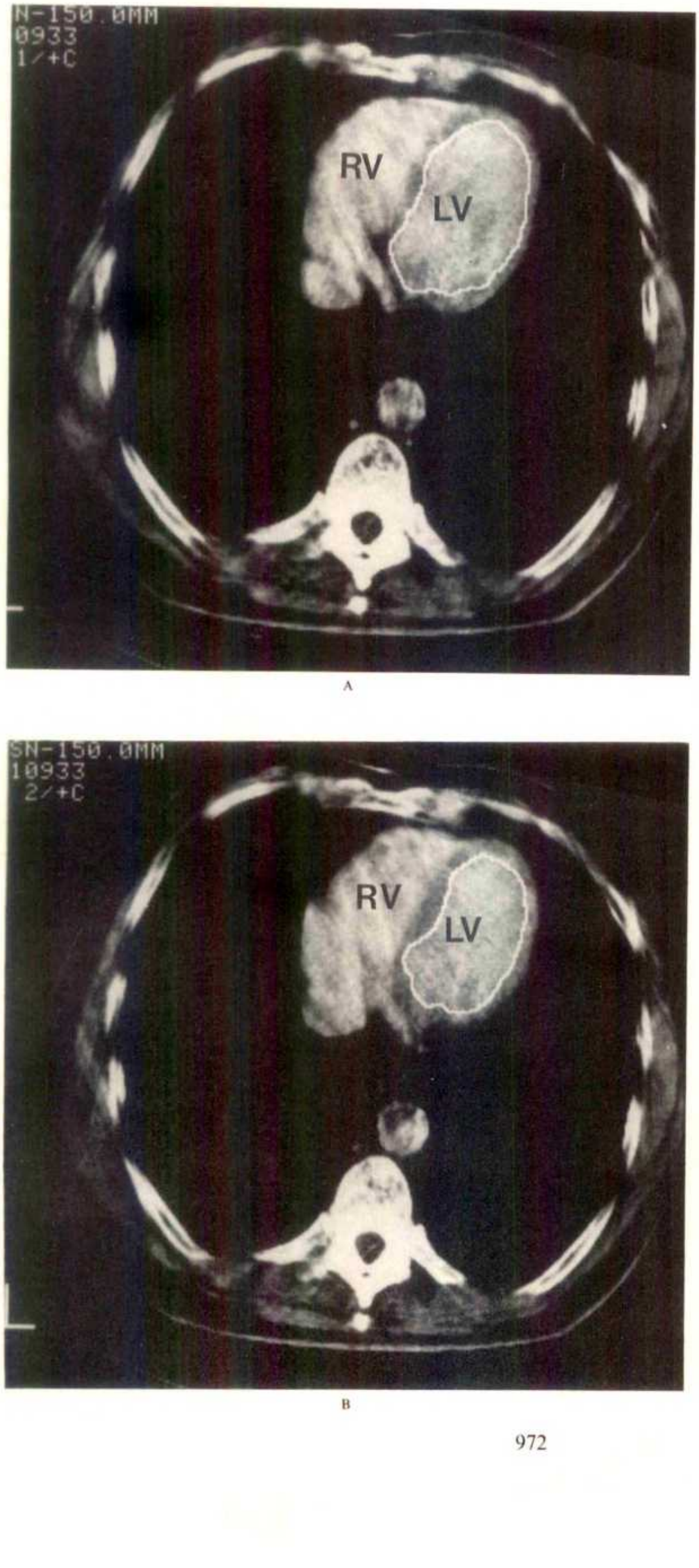


FIG. 2.

Electrocardiographically gated reconstructed images at mid-ventricular level with the left-ventricular cavity traced round: (A) end-diastole, (B) end-systole. LV = left ventricle, RV = right ventricle.

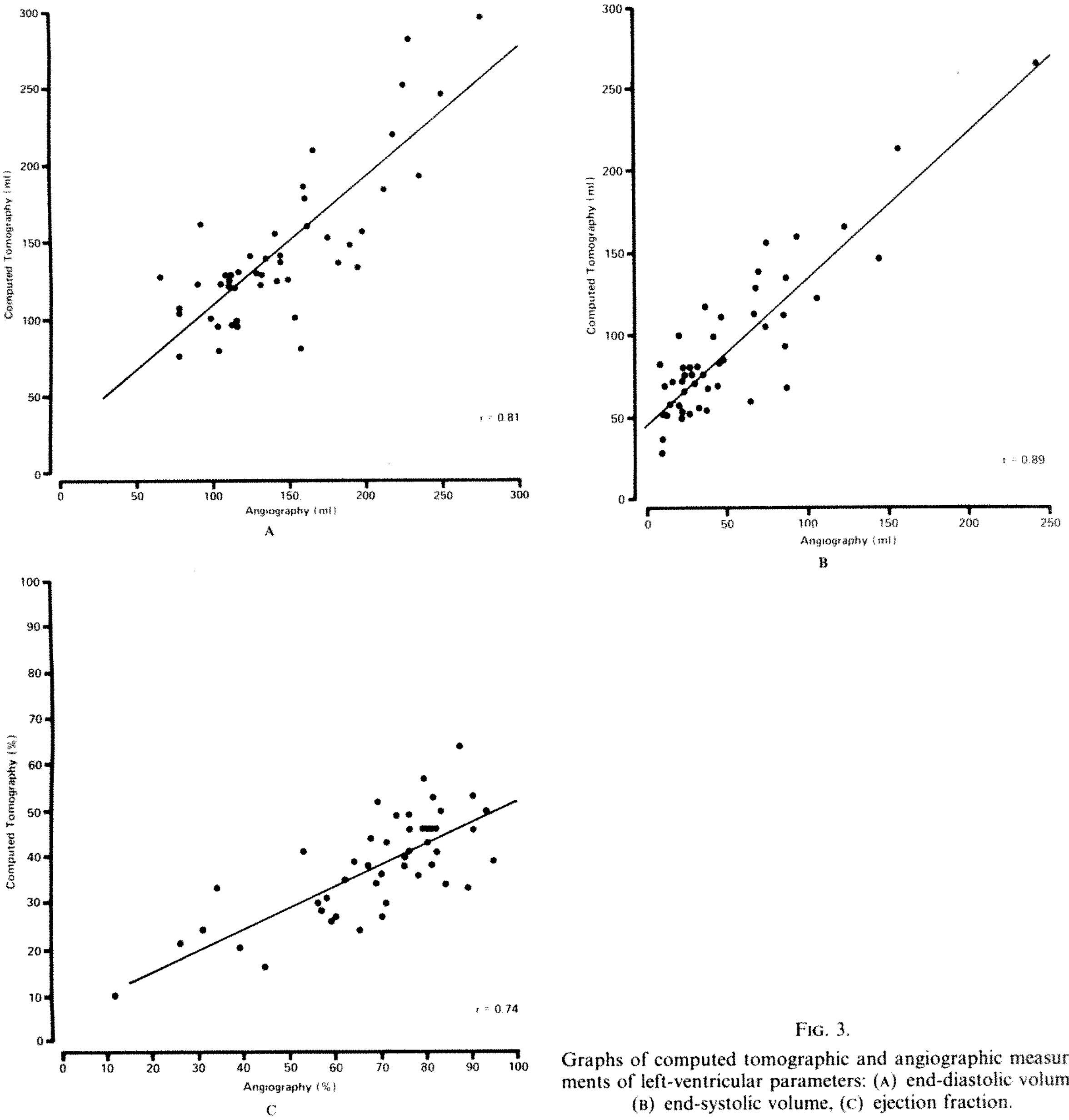


FIG. 3.

Graphs of computed tomographic and angiographic measurements of left-ventricular parameters: (A) end-diastolic volume, (B) end-systolic volume, (C) ejection fraction.

dilution of contrast medium (unpublished data). This technique is also dependent upon the use of geometric formulae for calculating volumes.

More recently, magnetic resonance imaging (MRI) has provided unique advantages in the diagnosis and assessment of cardiac disease (Jenkins & Isherwood, 1987). These include a high intrinsic contrast between flowing blood and adjacent chamber wall without the use of contrast medium, and the ability to image in any plane and in any phase of the cardiac cycle without ionising radiation. Magnetic resonance imaging, using multiple or single sections (Longmore et al, 1985; Love et al, 1985), has been shown to be an accurate method in ventricular measurement and in the study of cardiac function. Furthermore, complementary information can be obtained from blood-flow measurements. Access to MRI is at present, however, both limited and expensive.

Computed tomography, while theoretically providing more accurate linear and area measurements than other non-invasive techniques (Xhu et al, 1986) does, of course, have limitations. The gating "window" is 100 ms. This should not be a problem with measurements at end-diastole; end-systole, however, occupies a much shorter time (40–50 ms) and gated CT will therefore incorporate data collected before and after end-systole. This will inevitably give an over-estimation of end-systolic volume and the ejection fraction will therefore be underestimated—facts confirmed in this study. It may be possible, if enough patients were studied, to produce a correction factor for end-systolic volume.

In view of the time taken to perform a complete study of the left ventricle (approximately 5 min), relatively low doses of contrast medium per unit time have to be used and therefore detection of the endocardial border can be difficult.

For the same reason, as each level studied takes 35 s, respiratory movement can create problems and in patients with significantly impaired left-ventricular function the technique becomes impractical.

Despite these difficulties, computed tomographic measurements of left-ventricular function compared well with left-ventricular angiography in this study.

It is possible that as CT employs direct measurements it is a more accurate technique than left-ventricular angiography in assessing left-ventricular dimensions, especially when left-ventricular wall motion is abnormal. There is, however, no other method available to confirm this hypothesis.

Scanners with scan times in the order of milliseconds are now available (Lipton et al, 1984) and in the future, therefore, CT may have a significant role in the non-invasive investigation of left-ventricular function.

REFERENCES

BODENHEIMER, M. M., BANKA, V. S. & HELFANT, R. H., 1980. Nuclear cardiology. Radionuclide angiographic assessment of left ventricular contraction: uses, limitations and future directions. *American Journal of Cardiology, 45*, 661–673.

BRUNDAGE, B. H. & LIPTON, M. J., 1982. The emergence of computed tomography as a cardiovascular diagnostic technique. *American Heart Journal, 103*, 313–316.

DODGE, H. T., SANDLER, H., BALLEW, D. W. & LORD, J. D., 1960. The use of biplane angiocardiography for the measurement of left ventricular volume in man. *American Heart Journal, 60*, 762–776.

FEIGENBAUM, H., 1981. *Echocardiography*, 3rd edit. (Lea and Febiger, Philadelphia), pp. 109–110.

FOSTER, C. J., 1987. *The application of computed tomography to ischaemic heart disease*. M. D. Thesis, University of Bristol.

GIBSON, D. G., 1973. Estimation of left ventricular size by echocardiography. *British Heart Journal, 35*, 128–134.

JENKINS, J. P. R. & ISHERWOOD, I., 1987. Magnetic resonance (MRI) of the heart—a review. In *Recent Advances in Cardiology*. Ed. by D. J. Rowlands (Churchill Livingstone, Edinburgh), in press.

KENNEDY, J. W., TRENHOLME, S. E. & KASSER, I. S., 1970. Left ventricular volume and mass from single-plane cineangiocardiogram. A comparison of anteroposterior and right anterior oblique methods. *American Heart Journal, 80*, 343–352.

KRONENBERG, M. W., PRICE, R. R., SMITH, C. W., ROBERTSON, R. M., PERRY, J. M., PICKENS, D. R., DOMANSKI, M. J., PARTAIN, C. L. & FREISINGER, G. C., 1983. Evaluation of left ventricular performance using digital subtraction angiography. *American Journal of Cardiology, 51*, 837–842.

LIPTON, M. J., HIGGINS, C. B., FARMER, D. & BOYD, D. P., 1984. Cardiac imaging with a high speed cine-CT scanner: preliminary results. *Radiology, 152*, 579–582.

LONGMORE, D. B., KLIPSTEIN, R. H., UNDERWOOD, S. R., FIRMIN, D. N., HOUNSFIELD, G. N., WATANABE, M., BLAND, C., FOX, K., POOLE-WILSON, P. A., REES, R. S. O., DENISON, D. & MCNEILLY, A. M., 1985. Dimensional accuracy of magnetic resonance in studies of the heart. *Lancet, i*, 1360–1362.

LOVE, H. G., ZHU, X. P., JENKINS, J. P. R., WATERTON, J. C., ISHERWOOD, I. & ROWLANDS, D. J., 1985. Functional magnetic resonance imaging of the heart. In *Proceedings of the Fourth Annual Meeting of the Society of Magnetic Resonance in Medicine*, pp. 667–668.

MANCINI, G. B. J., PECK, W. W., SLUTSKY, R. A., MATTREY, R. F. & HIGGINS, C. B., 1983. Pharmacologically induced changes in wall thickening dynamics and mid-ventricular volumes in dogs assessed by prospectively gated computed tomography. *American Journal of Cardiology, 51*, 1729–1743.

MATTREY, R. F., SLUTSKY, R. A., LONG, S. A. & HIGGINS, C. B., 1983. In vivo assessment of left ventricular wall and chamber dynamics during transient myocardial ischaemia using prospectively ECG gated computerised transmission tomography. *Circulation, 67*, 1245–1251.

SAGEL, S. S., WEISS, E. S., GILLARD, R. G., HOUNSFIELD, G. N., JOST, G. T., STANLEY, R. J. & TER-POGOSIAN, M. M., 1977. Gated computed tomography of the heart. *Investigative Radiology, 12*, 563–566.

YANG, S. S., BENTIVOGLIO, L. G., MARANHAO, V. & GOLDBERG, H., 1978. *From Cardiac Catheterisation Data to Haemodynamic Parameter*, 2nd edit. (F. A. Davis Co., Philadelphia), pp. 124–126.

ZHU, X. P., CHECKLEY, D. R., HICKEY, D. S. & ISHERWOOD, I., 1986. Accuracy of area measurements made from MR images compared with computed tomography. *Journal of Computer-Assisted Tomography, 10*, 96–102.

1987, *The British Journal of Radiology*, *60*, 975–979 OCTOBER 1987

Pitfalls in interpretation of computed tomography prior to second-look laparotomy in patients with ovarian cancer

By *Alison R. Calkins, M.D., Frederick B. Stehman, M.D., Justin L. Wass, M.D., Lynda R. Smirz, M.D. and James H. Ellis, M.D.

Departments of Radiology, and Obstetrics and Gynecology, Indiana University Hospitals, Indianapolis, Indiana, USA

(*Received March 1986 and in revised form December 1986*)

ABSTRACT

Fifty-seven patients with ovarian cancer were assessed with computed tomography (CT) prior to undergoing second-look laparotomy. All patients were clinically free of disease following chemotherapy. Patients were scanned from the top of the liver to the symphysis pubis using oral, rectal and intravenous contrast medium. Tumour was correctly identified on CT scan in nine of 25 patients who had visible evidence of cancer at laparotomy. However, in the remaining 16 patients peritoneal studding was present and was not detected. Tumours smaller than 1.5 cm in size were not found by CT scanning. Computed tomography showed abnormality in eight of 32 patients subsequently found to be free of disease. Fine-needle aspiration cytology, bolus contrast injection and repeat scanning with additional oral contrast medium could have assisted in these circumstances. As persistent disease is by definition, a contraindication to second-look laparotomy, aggressive pre-operative assessment will spare some patients unnecessary surgery. However, CT cannot detect the small nodules often present in ovarian cancer, and thus, normal scans cannot replace surgical restaging.

As new combination chemotherapy regimens produce a high percentage of long-term responses in ovarian cancer (Ehrlich et al, 1983), an increasing number of patients require surgical restaging to assess their need for continued therapy. Initial surgery to remove bulk disease results in many patients starting chemotherapy without clinically measurable disease. It then becomes difficult to know how much therapy is "enough". All drugs have unpleasant side-effects, and as prolonged therapy with alkylating agents is recognised to be associated with an increased risk of acute leukaemia (Reimer et al, 1977), therapy should be discontinued as soon as possible. Although it is invasive, second-look laparotomy, *i.e.* planned exploratory surgery for patients who have responded to an established course of chemotherapy, has gained acceptance as a standard procedure for assessment of disease status. Although further therapeutic decisions are based on surgical findings, the operation itself is diagnostic in nature, *i.e.* patients with obviously persistent tumour are, by definition, not candidates for second-look.

We have used computed tomography (CT) pre-operatively in these patients to assess their disease status. This report compares the findings at surgery with the pre-operative CT assessments.

METHODS

From January 1, 1974 to May 1, 1985, 57 patients with ovarian cancer underwent a second-look laparotomy after CT scanning of the abdomen and pelvis. All patients had completed a prescribed course of chemotherapy and were clinically free of disease at the time of their surgery.

Between 1974 and January 1982, 26 patients were scanned on an EMI 5005 second-generation scanner with an 18 s scan time. After January 1982, a third-generation Philips Tomoscan 310 with a 4.8 s scan time was used. Oral contrast ($n = 52$), intravenous contrast ($n = 52$), rectal contrast ($n = 36$) and vaginal tampons ($n = 18$) were used to help identify normal structures. One patient received no contrast. Scans were obtained from the top of the liver through to the symphysis pubis at an average of 18.4 mm apart (range 12–20 mm). In 36 patients, the pelvis was scanned at smaller increments, averaging 12.5 mm (range 10–13 mm). The slices were 1 cm in thickness.

All radiographs were interpreted by a radiologist after reviewing relevant clinical information. Pre-operative consultation between the attending gynaecological oncologist and radiologist was common. The radiographic interpretation was available to the surgeon at the time of operation. Particularly in the early years of the study, adjunctive procedures, such as abdominal ultrasound, CT-directed fine-needle aspiration (FNA) of suspicious areas and bolus intravenous contrast injection, were not routinely done. A CT-directed FNA was performed in three patients in an attempt to confirm the presence of disease.

All operations were performed or directed by a gynaecological oncologist. Free peritoneal fluid or peritoneal washings were sampled, as well as any areas of visible or suspected cancer. If no visible disease was present, multiple biopsies were taken. One patient had a laparoscopy only as a second-look procedure because of other severe medical problems.

---

*Present address: Division of Radiation Oncology, The Johns Hopkins Hospital, 600 N. Wolfe Street, Baltimore, MD 21205, USA. Tel. (301) 955-6980.

TABLE I

COMPARISON OF INITIAL INTERPRETATION WITH REVIEW

Initial interpretation prior to surgery	Interpretation after review	Surgical findings
1 Nodularity of peritoneal surfaces over the liver and diaphragm	Normal variant	Tumour nodules
2 Borderline left para-aortic lymph node	Probably involved by cancer	Not biopsied, but not suspicious, had disease elsewhere
3 Increased reticular pattern in omentum	No change reticular pattern in omentum	6 cm omental mass

TABLE II

FINDINGS AT LAPAROTOMY

CT scan interpretation after review	Macroscopically positive	Macroscopically negative	Total
Positive	9	8	17
Negative	16	24	40
Total	25	32	57

For this report, all CT scans were reviewed by a single experienced radiologist (J.L.W.) who did not have knowledge of the surgical findings. Scans were examined for quality, and the size and location of all abnormalities were noted. These findings were then compared with the initial interpretation to assess consistency of interpretation.

RESULTS

All CT scans were considered to be adequate in demonstrating anatomical structures, although one was suboptimal due to the presence of retained lymphangiogram dye and multiple clip artefacts. The interpretation of the CT scan by our reviewer differed from the initial reading in only three of 57 patients (5.3%) (Table I).

Because CT is not expected to detect microscopic disease, for purposes of this review, a negative CT scan is regarded as a true negative and a positive CT scan regarded as a false positive in the patients with only microscopic disease. Two groups of patients were identified: 25 patients had macroscopic residual cancer found at operation, only nine of whom had an abnormal CT scan. Thirty-two patients had no visible disease. For purposes of clarity, patients are considered in four groups:

those with visible disease at surgery ($n = 25$),
those with no evidence of visible tumour ($n = 32$),
those with positive CT scans ($n = 17$), and
those with negative CT scans ($n = 40$).

These are represented schematically in Fig. 1 and Table II.

Of 25 patients with visible disease, the most common site of tumour (17 patients) was in the pelvis. Residual pelvic tumour nodules varied in size from 1 mm to 3 cm. Other locations of residual tumour were the visceral peritoneum in 11 patients, the omentum in six patients, the diaphragm in four, and the parietal peritoneum in six. Three patients had lymph-node involvement, and one had involvement of the endometrium. Intra-abdominal tumour masses ranged in size from 1 mm to 6 cm, with the largest mass found in the omentum.

Among these 25 women with visible tumour, nine had CT evidence suggesting possible recurrence. Of these nine, six women had neoplastic deposits identified

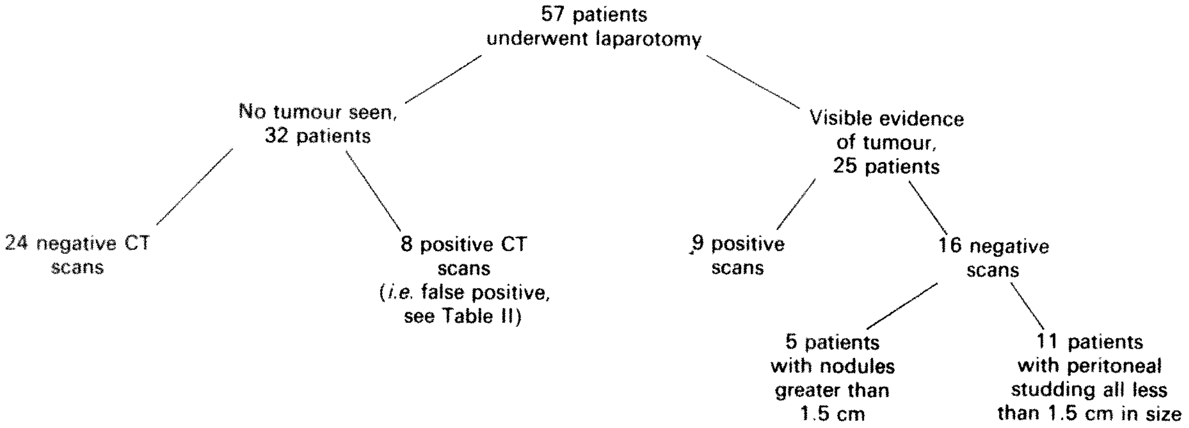

57 patients underwent laparotomy
No tumour seen, 32 patients
Visible evidence of tumour, 25 patients
24 negative CT scans
8 positive CT scans (*i.e.* false positive, see Table II)
9 positive scans
16 negative scans
5 patients with nodules greater than 1.5 cm
11 patients with peritoneal studding all less than 1.5 cm in size

FIG. 1.

Laparotomy findings compared with findings on CT.

TABLE III

REVIEW OF FALSE POSITIVE SCANS

Findings on CT	Reviewer's recommendation	Surgical findings
3 cm pelvic mass ?lymphocyst	Ultrasound or FNA	Lymphocyst
2 cm lung nodule unchanged from previous study	FNA	Not biopsied
Hepatic haemangioma vs metastasis	Ultrasound or FNA	Mass not found, laparotomy negative
4.5 cm pelvic mass ?uterus	Clinical correlation Pelvic ultrasound	Uterus
2 cm mass right lower quadrant ?node vs bowel	Repeat with additional oral contrast medium	Primary carcinoma of appendix
3 cm pelvic mass posterior to bladder; ?bowel	Repeat later with additional contrast medium	Recurrent tumour*, bowel loops
Nodes vs bowel loops sacral promontory and in pelvis	Repeat with additional oral contrast medium	Recurrent tumour*, bowel loops
5 cm pelvic mass lobular pelvic mass vs bowel loops	Repeat with additional oral contrast medium	Recurrent tumour*, bowel loops

*Microscopic only.

by CT scan and confirmed at laparotomy. All six of these were at least 2 cm in size. Two additional patients had new ascites, and one a new hydronephrosis. The largest mass, a 6 cm nodule in the omentum, was seen on the pre-operative CT scan and described as a "reticulated density in the omentum unchanged from the study of seven months prior". Although this was, in fact, tumour, pre-operatively it was felt possibly to represent fibrosis, and for reasons which could not be determined retrospectively no attempt was made to biopsy this percutaneously.

Thirty-two patients had no visible disease at laparotomy. Of these, 24 had negative CT scans. The remaining eight patients had suspicious or questionable scans. Their surgical findings are listed in Table III. We noted that, in accordance with our current practice, complementary studies could have been performed to elucidate better the nature of the various abnormalities in these eight patients.

Seventeen patients had abnormal findings on CT scan initially. Computed tomography correctly predicted the presence of tumour in nine of the 17 (52.9%). In one patient, a small mass was seen in the right lower quadrant. Although there was only microscopic evidence of persistent ovarian cancer, she was found to have an unsuspected primary carcinoma of the appendix. In the remaining seven patients no tumour was found.

TABLE IV

MASSES GREATER THAN 1.5 CM NOT IDENTIFIED BY CT

Location	Findings on CT
3 cm pelvic mass	Ascites only
6 cm omental metastasis	Negative
3 cm pelvic mass	Negative
3 cm mass on transverse colon	Negative
2 cm pelvic mass	Negative

Among 40 patients with normal findings on CT scan, macroscopically visible disease was present in 16. In most patients, this was studding of peritoneal surfaces, but individual lesions were too small to allow detection by CT. However, five masses greater than 1.5 cm in size were missed.

We reviewed these five scans to try to identify these masses retrospectively (Table IV). In all cases, the scans were felt to be of adequate quality. In one patient, new ascites was seen and the scan was interpreted as positive initially. In retrospect her pelvic mass was felt to be obscured by isodense abdominal fluid. In the other four cases, the masses could not be identified. They thus represent truly false negative CT scans. Figures 2–4 are the scans from three of these patients.

DISCUSSION

The introduction of cisplatin-containing combination chemotherapy has greatly improved the complete remission rates in ovarian cancer (Ehrlich et al, 1983).

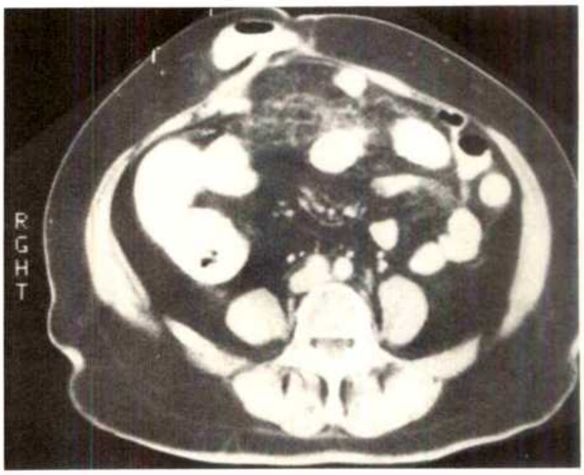


FIG. 2.

Computed tomography scan showing ventral hernia and increased but stable reticular pattern in the omentum just posterior to the hernia. At surgery, this was a 4 cm × 4 cm × 6 cm omental plaque.

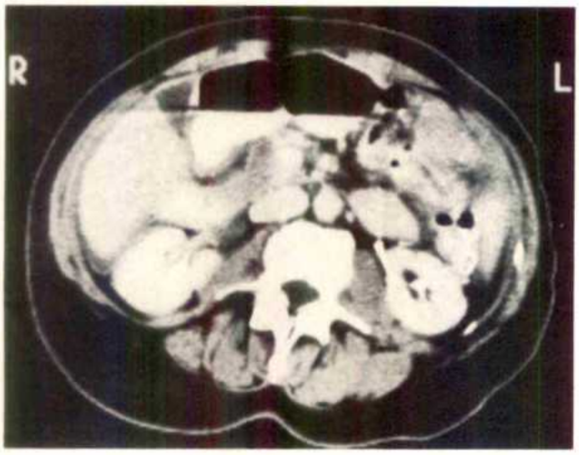


FIG. 3.

Ascites was noted at the posterior tip of the liver. At surgery, this patient had diffuse peritoneal carcinomatosis with a 3 cm × 3 cm × 3 cm omental mass and 3 cm implants in the pelvis.

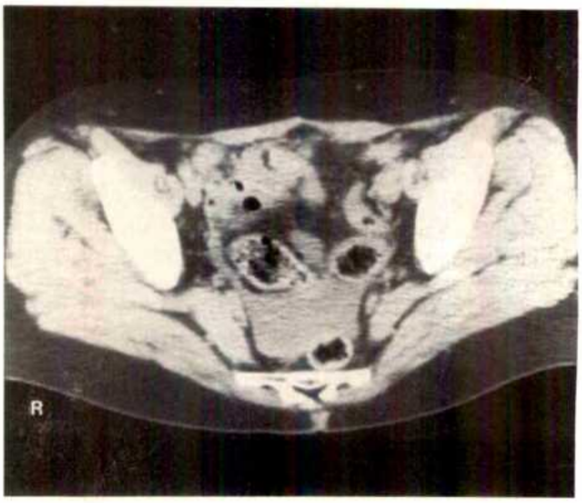


FIG. 4.

A small amount of ascites is present just anterior to the rectum. At surgery, miliary implants were present.

Second-look laparotomy has been used to determine whether patients who are clinically free of disease are pathologically free of disease. The findings from laparotomy are used to determine the need for continued or alternative therapy. Patients with residual disease do not do well and "second-effort" debulking is of little benefit (Vogl et al, 1984). Patients with persistent but microscopic disease can be offered alternative therapy. Treatment has generally been discontinued if the second-look is entirely negative. However, even this surgical evaluation is not ideal. In our own series (Smirz et al, 1985), 33% of the patients with no evidence of disease at second-look laparotomy have relapsed.

Although, ideally, no patient with persistent disease should undergo second-look surgery, it is unrealistic to expect that patients with microscopic disease only could be separated radiographically. However, these cases are rare: only nine of 57 patients in our experience. The group of major concern consists of those 16 patients with macroscopic disease which was not recognised pre-operatively.

Johnson et al (1983) reported that CT may be more accurate than clinical staging in ovarian carcinoma, largely because of its ability to visualise the liver, retroperitoneum and small amounts of ascites. Nevertheless, small nodules are a problem and the resolution of tumour nodules depends on their location, patient habitus and the relationship of the nodules to other isodense structures. Nodules of 2 mm may be seen in the lungs, but larger masses may be missed in the omentum, peritoneum, mesentery, and pelvis (Wittenberg, 1983). Kerr-Wilson et al (1984) found that masses less than 2 cm were not seen in the abdomen and one omental plaque 6 cm in size was missed. This agrees well with our experience as nodules smaller than 2 cm were not seen, and we also misinterpreted two large omental masses.

Goldhirsh et al (1983) reported that CT gave correct information about nodal metastases in 85% of cases if the nodes were greater than 1.5 cm in size. However, non-neoplastic adenopathy could lead to a false positive CT interpretation. Five of our patients had suspected nodal disease on CT. In only two cases was this confirmed at laparotomy. One patient had multiple nodes sampled and all were negative for tumour. In the other two patients, the nodes were considered normal to palpation or were not sampled. No unsuspected lymphadenopathy was found at operation in the other 52 patients. We found, as did Brenner et al (1985), that small amounts of ascites were readily detected by CT. Both of our patients with ascites had disease at surgery.

In the later years of this study, additional procedures were used to characterise CT abnormalities better. Ultrasound, FNA and rescanning with additional oral contrast medium were all used. We have found FNA, in particular, to be a reliable and cost-effective method for documenting the presence of disease and eliminating the need for laparotomy (Moriarty et al, 1986). Magnetic resonance imaging was found to be no better than CT in 38 patients with various gynaecological tumours, including nine patients with ovarian cancer (Bies et al, 1983).

Brenner et al (1985) reported a high false negative rate (22 out of 52) among patients assessed with CT prior to second-look surgery in ovarian cancer. However, they do not specify the total patient population at risk. During the period of this review, over 500 patients with ovarian cancer were treated at our institution. We do not know how many of these patients were thought to be disease-free on clinical grounds, only to be rejected for second-look on the basis of their CT scans. Determination of sensitivity, specificity, or negative predictive value can only be made if the total "*n*" is known. Some authors (Stern et al, 1981; Goldhirsh et al, 1983; Kerr-Wilson et al, 1984; Brenner et al, 1985) have been disappointed with the accuracy of CT scanning in ovarian carcinoma, but unless all patients who have undergone CT scanning are included in the analysis, whether they had second-look laparotomy or not, the accuracy of the study cannot be determined. It is our opinion, that in a busy gynaecological service, CT scanning has helped reduce the number of avoidable laparotomies.

We recommend CT scanning in all patients prior to second-look laparotomy. Aggressive use of adjunct studies such as ultrasound, rescanning with additional contrast medium or vaginal tampons, and CT-directed fine-needle aspiration should improve diagnostic accuracy in cases of doubt.

REFERENCES

Bies, J. R., Ellis, J. H., Kopecky, K. K., Sutton, G. P., Klatte, E. C., Stehman, F. B. & Ehrlich, C. E., 1983. Assessment of primary gynecologic malignancies: comparison of 0.15-T resistive MRI with CT. *American Journal of Roentgenology, 143,* 1249–1257.

Brenner, D. E., Shaff, M. I., Jones, H. W., Grosh, W. W., Greco, F. A. & Burnett, L. S., 1985. Abdominopelvic computed tomography: evaluation in patients undergoing second-look laparotomy for ovarian carcinoma. *Obstetrics and Gynecology, 65,* 715–719.

Ehrlich, C. E., Einhorn, L., Stehman, F. B. & Blessing, J., 1983. Treatment of advanced epithelial ovarian cancer using cisplatin, adriamycin and cytoxan—the Indiana University experience. *Clinical Obstetrics and Gynecology, 10,* 325–335.

Goldhirsh, A., Triller, J. K., Greiner, R., Dreher, E. & Davis, B. W., 1983. Computed tomography prior to second-look operation in advanced ovarian cancer. *Obstetrics and Gynecology, 623,* 630–634.

Johnson, R. J., Blackledge, G., Eddleston, B. & Crowther, D., 1983. Abdominopelvic computed tomography in the management of ovarian carcinoma. *Radiology, 146,* 447–452.

Kerr-Wilson, R. H., Shingleton, H. M., Orr, J. W. & Hatch, K. D., 1984. The use of ultrasound and computed tomography scanning in the management of gynecologic cancer patients. *Gynecologic Oncology, 18,* 54–61.

Moriarty, A. T., Glant, M. D. & Stehman, F. B., 1986. The role of fine needle aspiration cytology in the management of gynecologic malignancies. *Acta Cytologica, 30,* 59–64.

Reimer, R. R., Hoover, R., Fraumeni, J. F. & Young, R. C., 1977. Acute leukemia after alkylating-agent therapy of ovarian cancer. *New England Journal of Medicine, 297,* 177–181.

Smirz, L. R., Stehman, F. B., Ulbright, T. M., Sutton, G. P. & Ehrlich, C. E., 1985. Second-look laparotomy after chemotherapy in the management of ovarian malignancy. *American Journal of Obstetrics and Gynecology, 152,* 661–668.

Stern, J., Buscema, J., Rosenshein, N. & Siegelman, S., 1981. Can computed tomography substitute for second-look operation in ovarian carcinoma? *Gynecologic Oncology, 11,* 82–88.

Vogl, S. E., Seltzer, V., Calanog, A., Moukhtar, M., Camacho, F., Kaplan, B. H. & Greenwald, E., 1984. "Second-effort" surgical resection for bulky ovarian cancer. *Cancer, 54,* 2220–2225.

Wittenberg, J., 1983. Computed tomography of the body. *New England Journal of Medicine, 309,* 1160–1165.

Book reviews

A Colour Atlas of Angina Pectoris. By L. M. Shapiro, C. A. Warnes and K. M. Fox, pp. 200, 1987 (Wolfe Medical Publications, London), £30.00.
ISBN 0-7234-0934-X

Coronary artery disease and its main symptom, angina pectoris, is one of the commonest major conditions afflicting our society, with many books written about it. This one sets out to provide a comprehensive range of pictures of every aspect of those conditions which cause or mimic angina. As such, it brings together images from every specialty involved, ranging from plain radiographs and electrocardiograms to the forms of scanning currently available and the pathological changes associated.

This book is aimed at physicians and general practitioners, rather than the specialist in cardiology or the radiologist. It gives a view of the state of the art in imaging, and in some ways it has done well. For example, it gives a good review of aortic stenosis, but when it comes to minor conditions it is not sure what to include or what to leave out. I think that a pelvic radiograph in gross ankylosing spondylitis is barely relevant. Coronary artery disease, as shown by coronary angiography, however, should have had much more attention. There are 20 coronary angiograms divided between two main sections (they would have been better together). This is hardly a comprehensive assessment of coronary angiography, which is still, and will be for many years, the gold standard of investigation. The main value of the book has therefore been missed, as a reference of images particularly in coronary angiography.

The book has a place in the general hospital library because it does compile all disciplines, some well shown, particularly pathology. I do not, however, think it is of much value to the general radiologist, but it does have a limited value for the cardiac radiologist.

D. C. BETON

Radiology of Congenital Heart Disease, Vol 1. By K. Amplatz, J. H. Moller and W. R. Castañeda-Zuniga, pp. xvi+542, 1986 (Thieme Medical Publishers, New York), DM 248.
ISBN 0-86577-018-2 (New York)
3-13617-301-5 (Stuttgart)

This large textbook is the first of two volumes written by two radiologists and one paediatric cardiologist. No details are available of Volume 2 or what it will contain. Volume 1 is divided into three sections. The first consists of chapters on embryology, anatomy, radiation safety, classification, plain-radiograph appearances, cardiac catheterisation, angiographic equipment and angiography. There is a detailed section on plain-radiograph diagnosis which very clearly covers all the fundamentals. However, describing four-view plain-radiograph studies of the heart (with both obliques) does seem unnecessary and dated, as does using radiation and diagnostic pneumomediastinum to confirm thymic enlargement! Nowhere is the point made that as congenital heart disease is diagnosed and treated earlier, the plain radiograph has assumed much less importance. Surprisingly, echocardiography which has made such an impact on the diagnosis of congenital heart disease is not covered in this section. Later, in the chapters on specific cardiac conditions, it merits only the briefest of mentions.

There are good and very relevant chapters on radiation safety and cardiac catheterisation. The latter includes 37 diagrams showing the varying catheter courses through the heart which occur in different conditions. The chapters on angiography and angiographic equipment give a very good account of angled views but include much that seems rather unnecessary, *e.g.* much detail on catheter materials, injectors, the workings of film changers and cinecameras. Some mention of the emergent field of cardiac digital angiography would have been much more relevant. To Europeans, reading "that non-ionic contrast media probably have a place" seems rather backward.

Throughout this book, which is very well laid out, there are excellent drawings which supplement the good-quality X-ray plates.

Section 2 consists of conditions associated with a left-to-right shunt and Section 3 includes the outflow obstructive lesions. The pathology, clinical aspects, chest radiography, catheterisation and angiography are excellently covered in these chapters. Echocardiography is deficient as is any mention of newer aspects such as nuclear medicine, nuclear magnetic resonance and even interventional procedures.

In conclusion though this book has a somewhat dated approach it includes much good content. It fails in that it does not give a true picture of the modern imaging approach to congenital heart disease. It would be a useful addition to the shelves of libraries and to radiology and cardiology departments but would not be recommended as a first choice of standard reference textbook in congenital heart disease. Volume 2 remains to be seen but the price of the two-volume set is going to be a major factor against the individual buying this book.

J. F. REIDY

Cardiac Imaging: New Technologies and Clinical Applications. Ed. by Moms N. Kotler and R. M. Steiner, pp. xxi+454, 1986 (F.A. Davis Co., Philadelphia), $99.00.
ISBN 0-8036-5442-1

The title of this book sums up its contents and achievements completely. Subjects covered include the application of Doppler ultrasound techniques to the study of cardiac function and the applications of radionuclide scintigraphy, including the newer tomographic techniques. There are short chapters on magnetic resonance imaging of the heart, high-speed computed tomography, and digital vascular imaging.

The contributors point out the weaknesses as well as the strengths of their chosen techniques so that the reader has a balanced view of the value of each. For the non-specialists many contributors give considerable clinical background which aids in the understanding of the nature of the problem which is being solved.

I particularly liked the last two chapters, which give the methods of choice when investigating thoracic aortic dissection and pericardial disease, from the multitude of methods available.

The book is excellently produced on high-quality paper and well illustrated and reasonably up to date. Most chapters are pitched at the sort of level the non-specialist will understand and enjoy and the second part of the book is satisfyingly clinical in emphasis and satisfyingly balanced in its evaluation of the technique being discussed.

M. J. RAPHAEL

1987, *The British Journal of Radiology*, 60, 981–986

The measurement of heart size in the antero-posterior chest radiograph

By J. E. Kabala, M.B., CH.B., M.R.C.P. and P. Wilde, M.R.C.P., F.R.C.R.
Department of Radiodiagnosis, Bristol Royal Infirmary, Bristol, BS2 8HW

(*Received October 1986 and in revised form December 1986*)

ABSTRACT

A computed tomography model was used in eight patients to show how the heart diameter and cardiothoracic ratio might change between antero-posterior and postero-anterior positions. Results were compared with measurements made on erect antero-posterior chest radiographs taken on 103 patients without cardiac failure (controls) and 106 with cardiac failure. An upper limit of cardiothoracic ratio of 55% and of heart diameter of 165 mm in males and 150 mm in females was shown to provide useful discrimination between normal and abnormal heart size.

Heart size is usually measured on departmental postero-anterior (PA) chest radiographs. The patient's condition may prohibit this. The alternative use of an antero-posterior (AP) radiograph for assessment of heart diameter is traditionally considered unsatisfactory because of variables that include film–focus distance (FFD) and the anterior position of the heart in the chest, which together will influence magnification.

Two approaches were used to evaluate these problems. (1) A computed tomography (CT) model of the chest was used to show how projected PA and AP heart diameters might vary between individuals. (2) Cardiothoracic ratio and transverse heart diameter were measured on technically satisfactory standardised erect AP chest radiographs in two patient groups: Group A, 103 patients without cardiac failure, and Group B, 106 patients with known cardiac failure.

METHODS

Computed tomography model

Computed tomography scans of the chest were performed, in the supine position, on eight adults without clinical or radiographic evidence of cardiac failure and the sections showing the maximum cardiac diameter were examined. It was possible, by simple scale drawing, to project an expected cardiothoracic ratio and heart diameter from each subject in the PA and AP positions at an FFD of 150 cm (Fig. 1).

Direct measurements on AP chest radiographs

Erect AP chest radiographs of adult subjects, taken in 1983 and 1984, were obtained from the Bristol Royal Infirmary film library in a random manner.

Technically unsatisfactory radiographs were discarded if they showed any of the following features:

(1) thoracic wall or spinal deformity,
(2) inadequate inspiration (*i.e.* less than five ribs visible above the diaphragm anteriorly or nine ribs posteriorly),
(3) overexpanded chest (*i.e.* greater than seven ribs above the diaphragm anteriorly or 11 ribs posteriorly),
(4) inability to determine one or both heart borders with confidence (*e.g.* large pleural effusion),
(5) incompletely erect radiograph,
(6) mediastinal deviation, or
(7) significant rotation.

Subjects were included in the control group (Group A) if they fulfilled all of the following criteria:

(1) the radiograph was requested for a non-cardiac reason,
(2) there was no clinical evidence of heart failure,
(3) there was no upper-lobe vascular distension or pulmonary oedema (this assessment of cardiac failure takes no account of heart size).

Subjects were included in the cardiac failure group (Group B) if they fulfilled one or both of the following criteria:

(1) clinical cardiac failure,
(2) radiological evidence of cardiac failure (ignoring heart size).

The composition of the two groups is shown in Table I.

Transverse heart diameter was measured on each of the radiographs in the standard, textbook manner

TABLE I

COMPOSITION OF THE GROUPS USED FOR DIRECT MEASUREMENT OF CARDIOTHORACIC RATIO AND HEART DIAMETER

	Group A (no cardiac failure)	Group B (with cardiac failure)
No. of subjects	103	106
Mean age	56.7 years	64.1 years
Age range	16–92 years	37–91 years
No. of departmental films	61 (59%)	34 (32%)
No. of mobile-unit films	42 (41%)	72 (68%)
No. of male subjects	67 (65%)	60 (57%)
No of female subjects	36 (35%)	46 (43%)

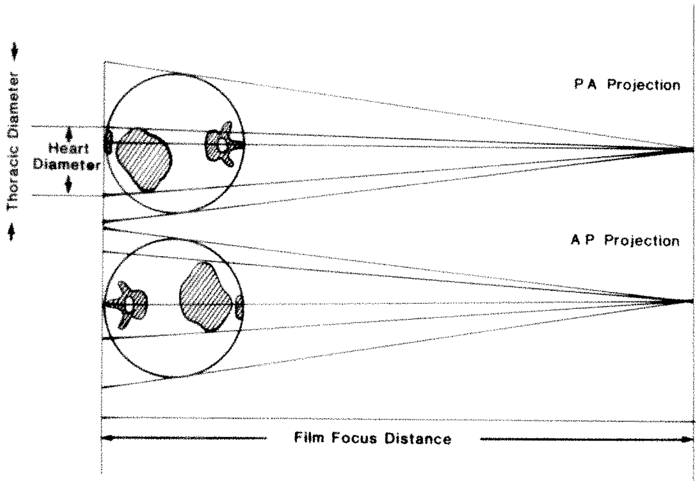


FIG. 1.
Measurement of projected heart diameter using CT sections.

(Jefferson & Rees, 1973; Simon & Hamilton, 1978; Steiner, 1980; Walker, 1985) by taking the sum of the horizontal distance from the midline to the most prominent part of the left heart border and the horizontal distance from the midline to the most prominent part of the right heart border. Maximum thoracic diameter was measured as the maximum horizontal distance between the internal margins of the chest wall.

RESULTS

Computed tomography model

The mean cardiothoracic ratio and heart diameter in each position are shown in Table II. The increase in mean heart diameter on changing from PA to AP position is 0.97 cm, and the increase in cardiothoracic ratio is 3.55%. The individual results are shown in Fig. 2.

Direct measurements on AP radiographs

The distribution of cardiothoracic ratios in the two patient groups is plotted in Fig. 3. It can be seen that there are two populations with relatively little overlap. The mean cardiothoracic ratio in subjects without cardiac failure (Group A) was 49.3%, compared with 63.1% in subjects with cardiac failure (Group B). A cardiothoracic ratio of 55% provided the best discrimination between the two groups. Of patients in Group A, 96% (99/103) had a cardiothoracic ratio of 55% or less, while 92% (97/106) of patients in Group B had a cardiothoracic ratio above 55%.

The distribution of heart diameters in the two groups is shown in Fig. 4. Again, two populations with a small overlap are shown. There is a mean heart diameter of 141.8 mm in Group A and 181.0 mm in Group B. Of subjects in Group A, 96% (99/103) had a heart diameter of 165 mm or less and 90% (95/106) of subjects in Group B had a heart diameter above 165 mm.

In Group A 65% of subjects were male and in Group B 57% of subjects were male. The cardiothoracic ratios for males and females in both groups have been plotted separately (Figs 5 and 6). Data obtained from these figures are displayed in Table III.

TABLE II

HEART DIAMETER AND CARDIOTHORACIC RATIO FROM THE CT MODEL (EIGHT SUBJECTS)

Projection	Mean heart diameter	Mean cardiothoracic ratio
AP	13.55 cm	48.9%
PA	12.58 cm	45.4%

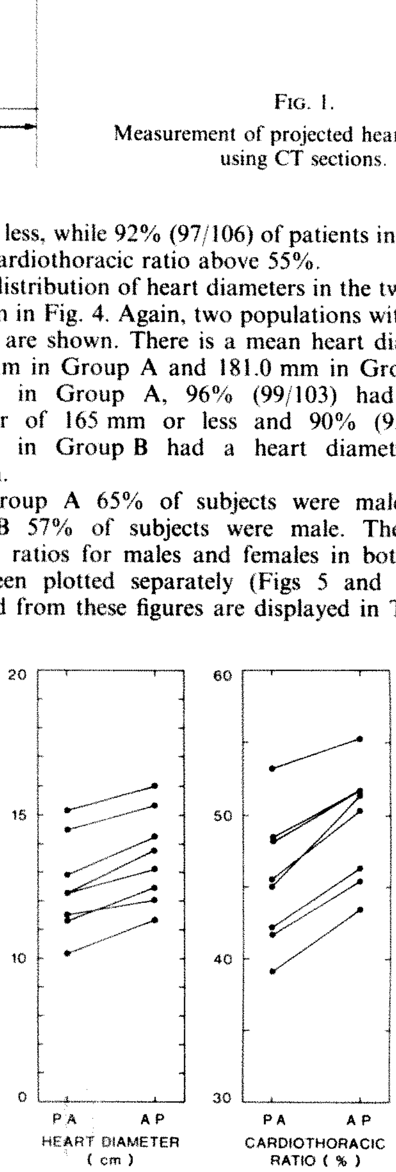


FIG. 2.
Cardiothoracic ratios and heart diameters predicted from CT models in PA and AP positions.

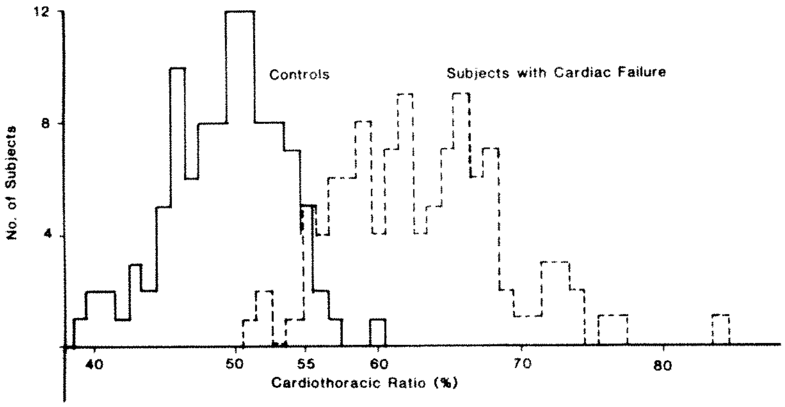


FIG. 3.
Cardiothoracic ratios in controls and in subjects with cardiac failure.

In Group A (without cardiac failure) there is no significant difference between male and female subjects: 97% of males (65/67) and 94% of females (34/36) had a cardiothoracic ratio of 55% or less.

In Group B (cardiac failure group) the mean cardiothoracic ratio of female subjects was significantly higher than that of male subjects, but 90% (54/60) of males and 93% (43/46) of females had a cardiothoracic ratio above 55%. It was concluded that a cardiothoracic ratio of 55% is equally useful as an upper limit of normal in both sexes.

The heart diameters for males and females were plotted separately (Figs 7 and 8). Data from these graphs are displayed in Table III. In male subjects, 165 mm appears to be a useful upper limit of normal in that 94% (63/67) of male subjects without cardiac failure have a heart diameter of 165 mm or less, and 97% of males with cardiac failure (58/60) have a heart diameter above 165 mm.

In females, not surprisingly, the heart diameters are significantly lower and a heart diameter of 150 mm offers useful discrimination between the normal and cardiac failure groups. Of females in Group A, 94% (34/36) have a heart diameter of 150 mm or less. Of females in Group B, 96% (44/46) have a heart diameter of 150 mm or less. In Group B 96% (44/46) of females have a heart diameter above 150 mm.

In departmental AP chest radiographs the FFD is 150 cm. Mobile chest radiographs are theoretically taken at an FFD of 120 cm. This is rarely measured and the methods used by the radiographers to estimate the FFD usually tend to overestimate it and bring the value of the FFD in mobile-unit radiographs closer to that in departmental films.

The cardiothoracic ratios and heart diameters measured on departmental and mobile-unit radiographs were compared and the results are shown in Tables IV and V. As can be seen, there is no consistent difference between measurements made on departmental and mobile-unit radiographs.

DISCUSSION

The study examined radiographs on subjects with and without cardiac failure. Cardiac failure was chosen because it is fairly easily diagnosed clinically and radiologically and is known to be associated with an enlarged heart. It was likely, therefore, to offer the best chance of showing discrimination between normal and abnormal heart size in AP chest radiographs.

The technique for measuring heart diameter and cardiothoracic ratio on PA chest radiographs is described in the standard radiological textbooks (Jefferson & Rees, 1973; Simon & Hamilton, 1978; Steiner, 1980; Walker, 1985). Heart size measured in

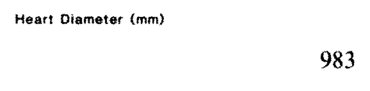


FIG. 4.
Heart diameters in controls and in subjects with cardiac failure.

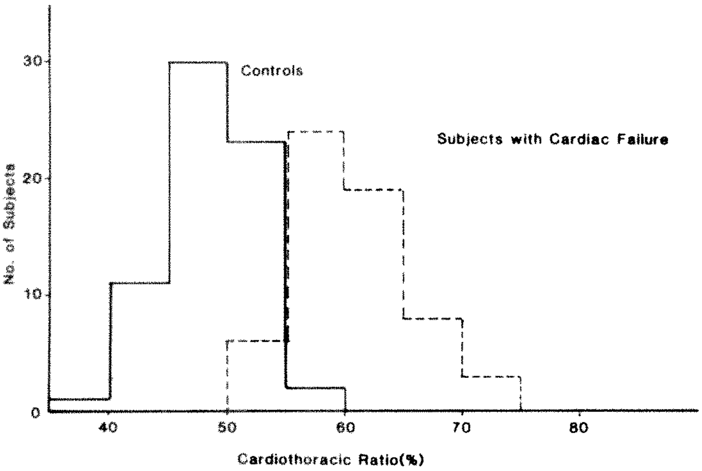


FIG. 5.
Cardiothoracic ratios in male subjects.

this way can be a useful parameter in the assessment of heart failure.

Traditionally, no mention is made of the use of the AP radiograph for measurement of heart size. This has its origin in the use of low-powered mobile-unit machines taking poor-quality chest radiographs at low FFDs. We feel it can be shown that study of good-quality radiographs taken at adequate FFDs (certainly greater than 120 cm and ideally 150 cm) allows an upper limit of normal heart size to be derived which includes most subjects without cardiac failure and excludes most with cardiac failure. In our study, 96% of normal subjects had a cardiothoracic ratio of 55% or less, while 92% of subjects with cardiac failure had a cardiothoracic ratio greater than 55%. Of males without cardiac failure, 94% had a heart diameter of 165 mm or less, while 97% of males with cardiac failure had a heart diameter above 165 mm. Of females without cardiac failure, 94% had a heart diameter of 150 mm or less and 96% with heart failure had a heart diameter above 150 mm.

In the PA radiograph, conventionally accepted upper limits of cardiothoracic ratio (50%) and heart diameter are well established. Caution, however, must be

TABLE III

COMPARISON OF CARDIOTHORACIC RATIOS AND HEART DIAMETERS IN MALES AND FEMALES

		No.	Mean cardiothoracic ratio (standard deviation)	Mean heart diameter (standard deviation)
Group A	Males	67	48.9% (3.9)	146 mm (13.2)
(no cardiac failure)	Females	36	50.0% (4.1)	133 mm (11.9)
Group B	Males	60	60.4% (4.6)	188 mm (14.3)
(cardiac failure)	Females	46	65.7% (6.7)	174 mm (14.5)

TABLE IV

COMPARISON OF CARDIOTHORACIC RATIOS IN MOBILE-UNIT AND DEPARTMENTAL RADIOGRAPHS

		Proportion with cardiothoracic ratio:	Mean cardiothoracic ratio
		55% or less	
Group A	Mobile unit	98% (41/42)	49.4%
(no cardiac failure)	Departmental	95% (58/61)	49.4%
		above 55%	
Group B	Mobile unit	90% (65/72)	61.6%
(cardiac failure)	Departmental	94% (32/34)	65.1%

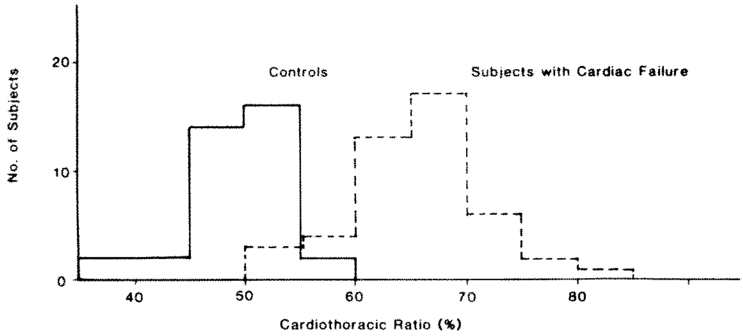


Fig. 6.
Cardiothoracic ratios in female subjects.

exercised in stating and using upper limits of heart diameter, which is known to vary with body build, age and sex. The upper limit of normal heart diameter in the male in PA radiographs is around 14.5 cm (Kerley, 1962). Throughout most of adult life the heart diameter in females is around 0.7–0.8 cm less than in males (Cowan, 1964), *i.e.* an upper limit of normal around 13.8 cm.

From these figures and the CT model, predicted values for upper limits of normal in the AP radiograph are: 53.5% for cardiothoracic ratio, 15.5 cm for male heart diameter and 14.8 cm for female heart diameter. These compare well with figures derived from our survey of chest radiographs.

Computed tomography is, of course, performed in the supine position and the results would not therefore be rigidly comparable with erect AP films.

The CT model was also used to examine the theoretical value of attempting to establish an upper limit of normal heart size on AP radiographs. It is important to show that the AP projection produces a similar amount of heart magnification in different individuals, *i.e.* a small heart on a PA radiograph remains small on the AP film and a large heart remains large. Figure 2 shows this to be the case, patients keeping their relative order well.

Conclusion

Measurement of heart size in erect AP chest radiographs may be a valid exercise. An upper limit of cardiothoracic ratio of 55% in males and females includes the vast majority (96%) of normal subjects and excludes most patients with cardiac failure (92%). An upper limit of transverse diameter of 165 mm in males and 150 mm in females excludes the majority of

TABLE V

Comparison of heart diameters in mobile-unit and departmental radiographs in normal and heart-failure groups

				Mean heart diameter
Males	Group A	Departmental	35/37 (95%)	146 mm
	(no cardiac failure) Proportion with heart diameter 165 mm or less	Mobile unit	28/30 (93%)	143 mm
	Group B	Departmental	9/10 (90%)	192 mm
	(cardiac failure) Proportion with heart diameter above 165 mm	Mobile unit	49/50 (98%)	187 mm
Females	Group A	Departmental	23/24 (96%)	134 mm
	Proportion with heart diameter 150 mm or less	Mobile unit	11/12 (92%)	132 mm
	Group B	Departmental	22/24 (92%)	170 mm
	Proportion with heart diameter above 150 mm	Mobile unit	22/22 (100%)	178 mm

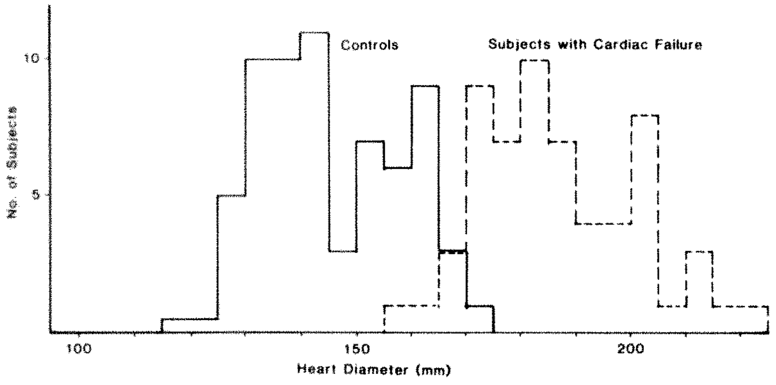


FIG. 7.
Heart diameters in male subjects.

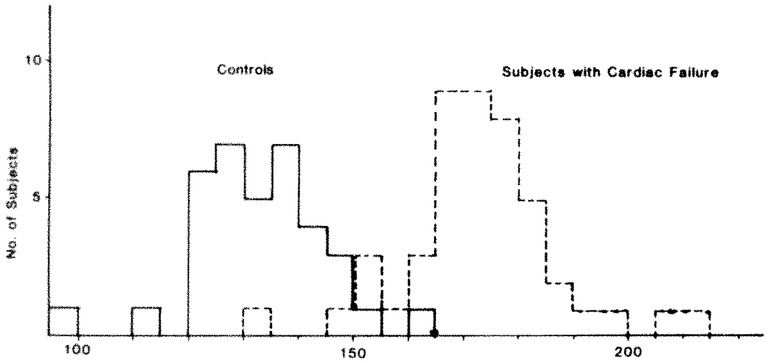


FIG. 8.
Heart diameters in female subjects.

subjects with cardiac failure (97% and 98% respectively) and includes most normal hearts (94%).

It should be emphasised that these conclusions apply only to technically satisfactory AP radiographs, those taken at a virtually full distance, straight and with the correct degree of inspiration.

REFERENCES

COWAN, N. R., 1964. The heart–lung coefficient and the transverse diameter of the heart. *British Heart Journal, 26*, 116–126.

JEFFERSON, K. & REES, S., 1973. Radiological anatomy and assessment of heart size. In *Clinical Cardiac Radiology*, (Butterworths, Sevenoaks), pp. 3–9.

KERLEY, P., 1962. X-ray measurements of the cardiovascular shadow. In *A Textbook of X-ray diagnosis*. Ed. by S. C. Shanks & P. Kerley (Lewis and Co. Ltd, London), pp. 22–25.

SIMON, G. & HAMILTON, W. J., 1978. The heart. In *X-ray Anatomy*. (Butterworths, Sevenoaks), pp. 137–167.

STEINER, R. E., 1980. The heart: techniques and normal appearances. In *A Textbook of Radiology and Imaging*. Ed. by D. Sutton (Churchill Livingstone, Edinburgh), pp. 448–459.

WALKER, J., 1985. Cardiac outline and chamber anatomy. In *A Textbook of Radiological Diagnosis*. Ed. by J. B. Partridge (Lewis and Co. Ltd, London), pp. 1–31.

1987, *The British Journal of Radiology*, 60, 987–992 OCTOBER 1987

Radiology of normal and abnormal gastric mucus*

By Eric Samuel, C.B.E., D.Sc. (Hon.) M.D., F.R.C.S., F.R.C.P.E., F.R.C.R.

Department of Radiology, University of Pretoria and Brenthurst Clinic, Johannesburg, Republic of South Africa

(*Received August 1986 and in revised form December 1986*)

ABSTRACT

Original surgical methods (selective vagotomy etc.) of lowering acid pepsin production in the stomach for the control of peptic ulceration have been mirrored by medical measures using H-antagonistic drugs. These have resulted in excessive quantities of mucus in the stomach. Such masses of mucus may give rise to pseudotumours in the stomach—mucomas either pure or of mixed type when the mucus is admixed with vegetable fibres. Distinction of these masses from others in the stomach is important for the establishment of correct treatment. The radiological and clinical features seen in six cases of gastric mucoma are described.

Peptic ulceration is so common in Western civilisation that a vast amount of medical effort has been directed to its aetiology, and the mechanisms of its production have been the subject of extensive research.

It is recognised that peptic ulceration occurs only in sites exposed to a mixture of gastric acid and pepsin and consequently appears in those parts of the alimentary canal, stomach, duodenum and oesophagus normally exposed to this mixture (Fig. 1). The balance between the digestive effects of the acid-pepsin complex and the protective effect of the mucous barrier is a delicate one.

The purpose of this paper is to draw attention to mucus production as a normal protective mechanism, to illustrate some gastric disturbances that may occur when its normal production and dispersal are inhibited by medical and surgical treatment, and to outline some of the radiological features which may be seen in these circumstances (Fig. 2).

Many modern surgical procedures employed in the treatment of peptic ulceration directly influence the production of the acid-pepsin mixture, with the result that the normal mechanism for the dispersal of mucus is destroyed (Cain et al, 1968; Goldstein et al, 1973; Rogers et al, 1973; Budd & McCreary, 1978). Some of the more powerful receptor H-antagonistic drugs used in medical therapy effectively inhibit the normal production of acid and pepsin and consequently an increased amount of mucus remains in the stomach.

Normal gastric mucus occurs either in solution or as a gel adhering to and covering the gastric mucosa (Bickel & Kauffman, 1981), the so-called "barrier mucus" (Corne et al, 1974), and is secreted by the tall columnar epithelial cells lining the gastric mucosa. The mucosal layer of the stomach is invaginated to form pits

---

Address for reprints: P.O. Box 370, Johannesburg 2000, RSA.

*Based on a paper delivered at the XVI International Congress of Radiology, Hawaii, 1985.

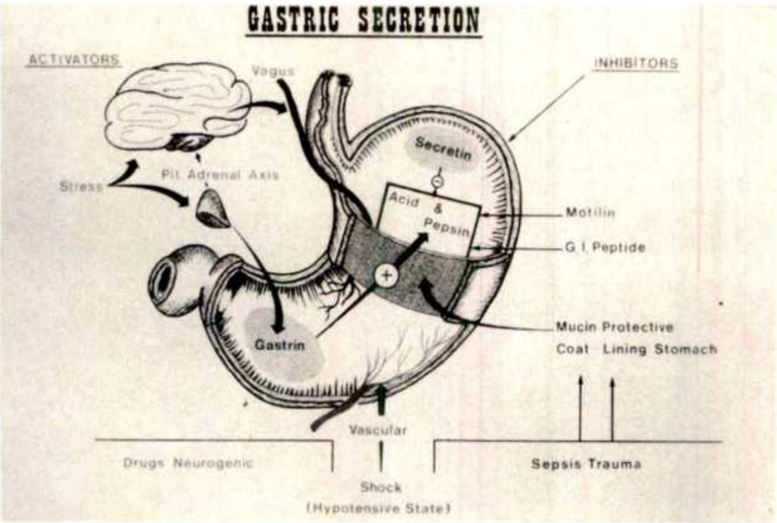


FIG. 1.

Line drawing of some of the factors that influence gastric secretion and mucus coating of the stomach.

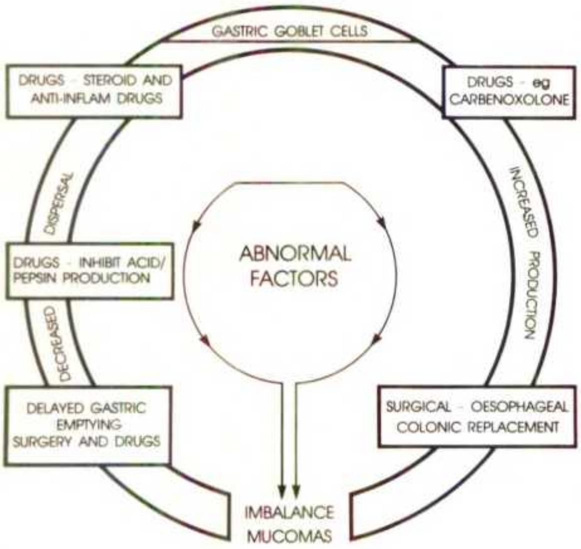

GASTRIC GOBLET CELLS
DRUGS - STEROID AND ANTI-INFLAM DRUGS
DRUGS - eg CARBENOXOLONE
DISPERSAL
INCREASED PRODUCTION
DRUGS - INHIBIT ACID/ PEPSIN PRODUCTION
ABNORMAL FACTORS
DECREASED
DELAYED GASTRIC EMPTYING SURGERY AND DRUGS
SURGICAL - OESOPHAGEAL COLONIC REPLACEMENT
IMBALANCE MUCOMAS

FIG. 2.

Line diagram illustrating some of the abnormal conditions that may result in the production of mucomas by altering the various stages in the mucus cycle.

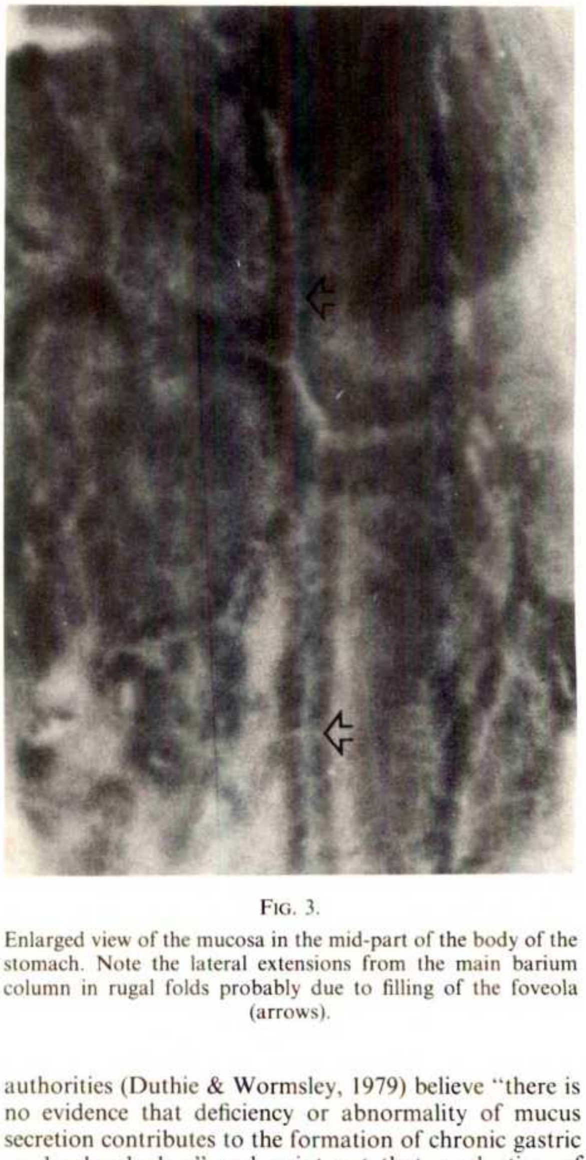


FIG. 3.

Enlarged view of the mucosa in the mid-part of the body of the stomach. Note the lateral extensions from the main barium column in rugal folds probably due to filling of the foveola (arrows).

or foveola (Fig. 3) which are lined by the gastric glands (cardiac, oxyntic and pyloric) (Shearman & Findlayson, 1982). These foveola contribute to the pattern of the gastric mucosa seen in good double-contrast studies—the areae gastricae pattern.

The alkalinity of the mucous barrier of the stomach decreases from the mucosal cell layer through the mucous barrier until the gastric lumen is reached. This progressively increasing alkalinity in the gastric wall inhibits the flow of hydrogen ions from the lumen into the gastric wall cells, preventing damage to these cells (Heatley, 1959).

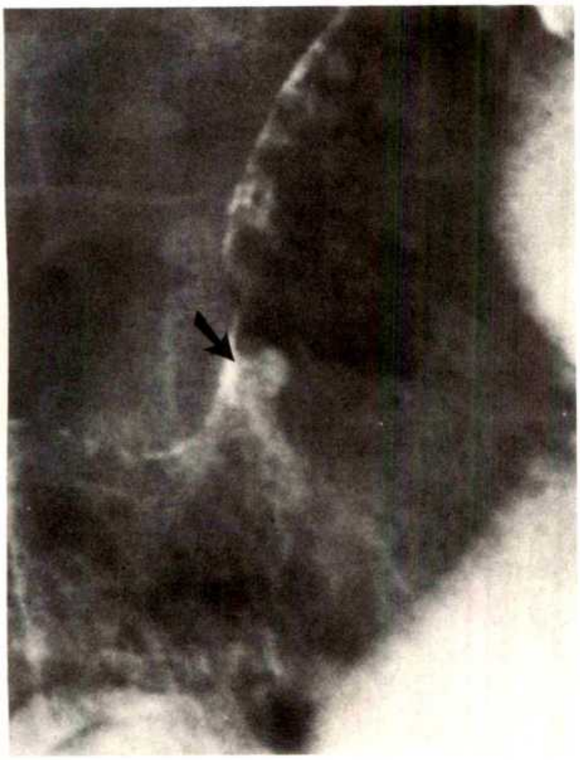
The foveola can be appreciated in all good double-contrast studies (Kreel, 1974; Mackintosh & Kreel, 1977) and in this series barium (E-Z-EM) and water mixture (30 ml) in 1 : 4 strength was used with two doses of Gastrast T (Toho Kagaku Kenysho Co.) tablets. Muscle relaxant was used only in exceptional cases. Unless the correct thickness of barium is layered on the gastric wall the foveola may be obliterated along with the areae gastricae pattern. Similar appearances may be seen when there is an excessively thick layer of mucus covering the gastric mucosa, preventing the entry of barium into the foveola to produce the delicate areae gastricae pattern.

The function of these foveola in the gastric mucosa is not fully understood; they may be associated with increasing the secretory capacity of the gastric mucosa or they may simply be a means of allowing stretching of the mucosa to accommodate the varying volume of the stomach.

Not all authorities agree on the protective function of the mucous barrier (Corne et al, 1974) and some authorities (Duthie & Wormsley, 1979) believe "there is no evidence that deficiency or abnormality of mucus secretion contributes to the formation of chronic gastric or duodenal ulcer" and point out that production of mucus is markedly decreased in pernicious anaemia and chronic gastritis.

Keto et al (1983) found no histological correlation between the size of the gastric foveola demonstrated in the areae gastricae pattern and the presence or absence of gastritis. Careful examination of the areae gastricae pattern, particularly between the rugal folds, reveals that the barium tracts are discontinuous, probably representing mucus lying in the gastric foveola.

When there is excessive mucus formation, the areae gastricae pattern may be obliterated but, equally, when there is gastric atrophy, areas bare of areae gastricae may be seen, which may also arise as a result of inadequate coating technique. Mucous globules (Fig. 4) have to be differentiated from other causes of defects in



the mucosal pattern, *e.g.* retained food particles, partly dissolved gas tablets and gastric polyps.

The abnormal mucus cycle is shown in Fig. 2, where it can be seen that abnormal quantities may occur either from increased production or from interference with normal dispersal mechanisms. Abnormal production may give rise to pure mucous masses in the stomach (mucomas) or, more commonly, mucus may be mixed with fibre, giving rise to a mixed type of mucoma.

Patients

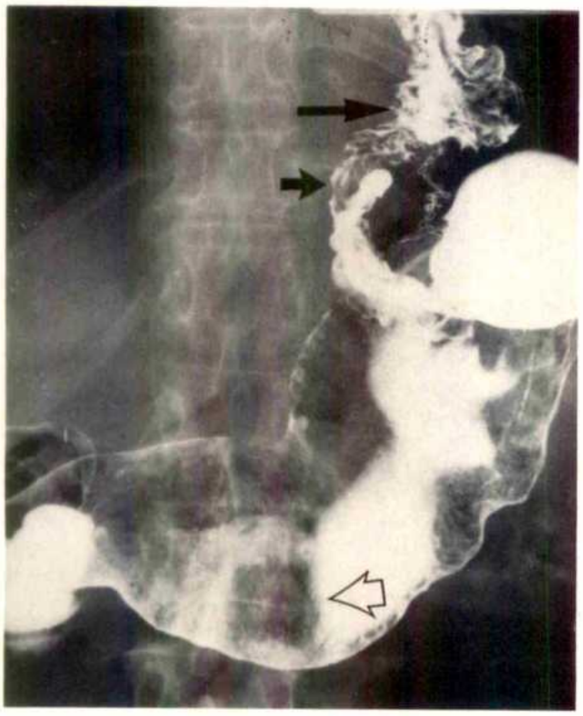
Nine cases of mucoma of the stomach, of pure and mixed types, have been seen in the last 6 years. The clinical details of six cases are shown in Table I, the clinical data on the other three being incomplete. All nine cases had had some form of oesophageal or gastric surgery. Two cases had colonic replacement for oesophageal strictures, one followed vagotomy and pyloroplasty, one followed repair of hiatus hernia and fundoplication, and the others had partial gastrectomies (Billroth I and Polya types). Two other cases not included in Table I also had operations for repair of hiatus hernia and fundal plication.

Fig. 4.

Mucous globules (arrow), covered with barium, attached to the lesser curve of the stomach.

TABLE I

Case	Age (years), sex	Clinical data	Radiological findings
1	62, male	Benign oesophageal stricture excised years previously with colonic replacement. Recent epigastric pain and discomfort	Interposed colonic segment between oesophagus and stomach acting as satisfactory conduit with no obstruction. Large, mixed type of mucoma freely movable in barium-filled stomach
2	52, male	Reflux dyspepsia, heartburn and belching for 15 years. Oesophagoscopy showed chronic oesophagitis, treated by partial oesophagectomy and colonic replacement. Five months later, upper epigastric symptoms treated by gastrostomy and pyloroplasty and removal of mucoma	Mixed type of mucoma freely movable in pyloric antrum
3	42, female	Gripping epigastric pain associated with nausea and vomiting for 3 years. Pyloroplasty and vagotomy 15 years previously for duodenal ulcer	Delayed gastric emptying and large, pure mucoma literally forming a cast of the stomach
4	35, female	Indeterminate epigastric symptoms with nausea; partial gastrectomy years previously for duodenal ulcer	Polya type partial gastrectomy with slow emptying of gastric remnant. Large gastric stump remaining, containing a large, mixed type of mucoma
5	68, female	Epigastric discomfort and varying degree of anorexia for a few years following a partial gastrectomy 20 years previously	Billroth I partial gastrectomy, narrowing of stoma and a large gastric stump with mixed type of mucoma
6	69, male	Six-year history of intestinal pain, worse over last 2 months. Five months previously, hiatus hernia repair followed by reflux oesophagitis noted on oesophagoscopy. Four months later presented complaining of wind. Gastrectomy 1 month later revealed a yellow, gelatinous mass with fibrous strands	Mixed type of mucoma in pyloric antrum which appeared to be causing intermittent pyloric obstruction



Pathological findings

The exact nature of the mucomas was determined in those cases (2 and 6) in which gastrectomy had been performed. In these, the mass was of a yellow-grey gelatinous nature, containing varying degrees of fibrous strands, probably vegetable fibres.

Other cases were treated by endoscopy, fragmentation of the mucoma and piece-meal removal; these were not subjected to histological examination.

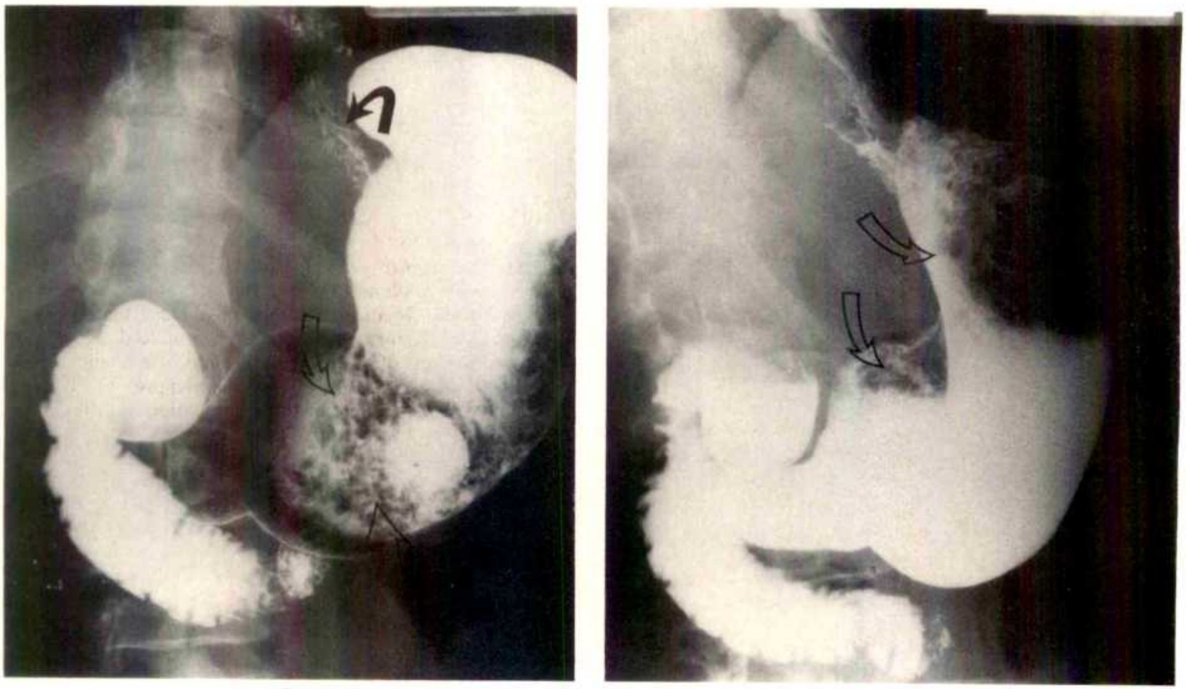
Radiological findings

The radiological feature of a mucoma is a mass in the gastric lumen, the mobility of which allows ready differentiation from a gastric neoplasm (Fig. 5).

The fact that mucomas most frequently arise in patients who have undergone gastric or oesophageal surgery makes the differentiation from retained food material important. The latter can be differentiated from mucomas by the fact that in the erect position it has an irregular, horizontal border above the ingested

Fig. 5.

Pure mucoma (open arrow) in the stomach showing smooth outlines and no mixture of the barium with the mucoma. The colonic/oesophageal replacement is shown (solid arrows).



A

B

Fig. 6.

(A) A supine radiograph showing mixed type of mucoma in the stomach (open arrows). The colonic/oesophageal replacement is shown by the characteristic mucosal pattern in the region of the lower oesophagus (solid arrow). (B) In the erect position two mucomas are shown (arrows). The rounded nature of the masses differentiates them from retained food.

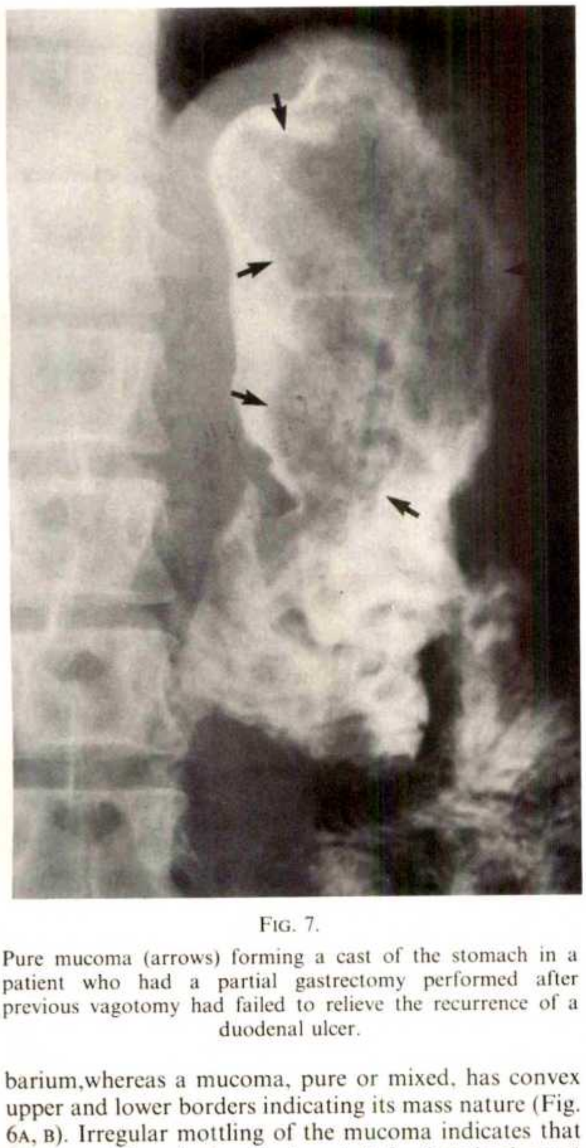


FIG. 7.

Pure mucoma (arrows) forming a cast of the stomach in a patient who had a partial gastrectomy performed after previous vagotomy had failed to relieve the recurrence of a duodenal ulcer.

barium, whereas a mucoma, pure or mixed, has convex upper and lower borders indicating its mass nature (Fig. 6A, B). Irregular mottling of the mucoma indicates that the mucus is mixed with ingested food (mixed type) whereas the pure mucoma does not show any such mottling. Pure mucomas may form a cast of the stomach, especially in patients who have stromal narrowing after a partial gastrectomy (Fig. 7). Fungal bezoars, which may develop in immunocompromised patients, may give appearances similar to mixed mucomas.

DISCUSSION

From a study of the cases it appears that two out of three factors are necessary for the production of mucomas:

(i) increased production of mucus;
(ii) delayed gastric emptying; and
(iii) decreased production of gastric acid and pepsin.

Increased mucus production may follow the administration of certain drugs, such as carboxolene (Allen & Garner, 1980) and prostacyclin (Pounder, 1984), but in the absence of any gastric delay the excess mucus is dispersed by digestion and passed on with digested food. Increased production of mucus may also occur following surgical treatment of an oesophageal stricture when the oesophagus is replaced by a colonic segment. In such cases the vagus is automatically sacrificed during surgery, hence delayed emptying occurs, together with an excessive production of mucus from the transposed colon. Two such cases (1 and 2) are seen in this series.

Decreased production of acid-pepsin complex following vagotomy, especially if not accompanied by pyloroplasty, produced two of the above factors, stasis and decreased dispersal (Cases 3 and 6).

Partial gastrectomy, especially if combined with delayed emptying, produces conditions necessary for mucoma development.

H-receptor antagonists, such as cimetidine and ramitidine hydrochloride, by suppressing acid and pepsin production, produce conditions in which one of the normal dispersing factors of mucus is inhibited, with resulting accumulation in the stomach. This is especially likely to occur if there is delay in gastric emptying as a result of previous vagotomy.

The clinical importance of recognition of these conditions lies in the fact that dyspeptic symptoms caused by mucomas are atypical and, as they often follow surgical treatment, they may be mistaken for recurrence of previous ulceration and the H-receptor antagonist dosage increased. Once recognised, the correct treatment is piece-meal removal through the gastroscope followed by oral acid-pepsin therapy.

ACKNOWLEDGMENTS

I am indebted to Mr Paul Marchand for allowing me to use his cases and supplying detailed clinical and surgical notes and to Dr A. Berezowski and Dr H. Krige for the details of two of the cases. The Medical Photography Department of the Universities of Pretoria and Edinburgh produced the graphics and reproductions of the radiographs and Mrs Shelley Taylor and Mrs Carmen Bedford typed the manuscript. E-Z-EM barium was used throughout this examination and the author acknowledges their generous support.

REFERENCES

ALLEN, A. & GARNER, A., 1980. Mucus and bicarbonate secretion in the stomach and their possible role in the mucosal protection. *Gut, 21*, 249–262.

BICKEL, R. & KAUFFMAN, I., 1981. Gastric gel mucus. *Gastroenterology, 80*, 770–775.

BUDD, D. C. & MCCREARY, M. L., 1978. Gastric phytobezoar—still another post gastrectomy syndrome. *American Surgeon, 44*, 104–107.

CAIN, D. M., MOOR, P. & PATTERSON, M., 1968. Bezoars, a complication of the post gastrectomy stage. *American Journal of Digestive Diseases, 13*, 801–809.

CORNE, S. J., MOMSEY, I., SNR & WOODS, R. J., 1974. A method for the quantitative estimation of gastric barrier mucus. *Proceedings of the Philosophical society, June,* 116–117.

DUTHIE, H. L. & WORMSLEY, K. G., 1979. *The Scientific Basis of Gastro-enterology.* (Churchill Livingstone, Edinburgh), p. 142.

GOLDSTEIN, H. M., COHEN, L. E., HAGEN, O. & WELLS, R. F., 1973. Gastric bezoar: a frequent complication in the post-operative ulcer patient. *Radiology, 107,* 341–344.

HEATLEY, N. G., 1959. Muco substance as a barrier to diffusion. *Gastroenterology 37,* 313–317.

KETO, P., SUORANTA, H., MYHARNICNIE, H. & NICKELS, J., 1983. Areae gastricae in gastritis; lack of correlation between age and histology. *American Journal of Roentgenology, 141,* 693–696.

KREEL, L., 1947. Recent advances in gastro-duodenal radiology. *Proceedings of the Royal Society of Medicine, 68,* 111–114.

MACKINTOSH, C. E. & KREEL, L., 1977. Anatomy of radiology of the areae gastricae. *Gut, 18,* 855–864.

POUNDER, R. E., 1984. Prostaglandins in ulcer therapy. *Medical News, 2,* 7.

ROGERS, L. F., DAVIS, E. K. & HARLE, T. S., 1973. Phytobezoar formation and food boli following gastric surgery. *American Journal of Roentgenology, 119,* 280–290.

SHEARMAN, D. J. C. & FINDLAYSON, N. D. C., 1982. *Disease of the Gastro-intestinal Tract and Liver* (Churchill Livingstone, Edinburgh), p. 125.

1987, *The British Journal of Radiology*, *60*, 993–995 OCTOBER 1987

Congenital diaphragmatic hernia: the prognostic significance of the site of the stomach

By T. Goodfellow, B.Sc., F.R.C.S., I. Hyde, F.R.C.P., F.R.C.R., *D. M. Burge, M.R.C.P., F.R.C.S. and *N. V. Freeman, F.R.C.S.

The Wessex Paediatric Radiology and *Paediatric Surgery Departments, Southampton General Hospital, Tremona Road, Southampton

(*Received January 1987*)

ABSTRACT

Congenital diaphragmatic hernia is associated with a significant mortality, despite intensive treatment. The degree of pulmonary vascular hypoplasia is the main factor affecting mortality. Various features have been considered to determine the prognosis in these infants. In this study a series of 50 consecutive cases of left-sided diaphragmatic hernia has been reviewed. The site of the stomach (abdominal or intrathoracic), demonstrated radiologically and confirmed at operation, has been related to the final outcome (survival or death). An abdominal site is associated with an excellent prognosis (6.2% mortality), while an intrathoracic site is associated with a 58.8% mortality.

Congenital diaphragmatic hernia is associated with a significant mortality in the neonatal period, despite intensive treatment (Simson & Eckstein, 1985). All patients, including those who survive, have a degree of bilateral pulmonary hypoplasia which is more marked on the ipsilateral side (Naeye et al, 1976; Levin, 1978). The degree of the pulmonary vascular abnormality is the main factor affecting mortality because this results in reduced pulmonary perfusion, persistent shunting from right to left and hypoxia (Bloss et al, 1980).

The majority of hernias (about 85%) are left sided and they may contain any or all of the following: stomach, small bowel, colon, liver and spleen. Various attempts have been made to predict the outcome in infants with a diaphragmatic hernia, mainly based on blood gas analysis and pH studies (Boix-Ochoa et al, 1974; Bohn et al, 1984). The aim of the present study was to ascertain whether the site of the stomach in a left-sided hernia had any prognostic significance.

METHODS

A retrospective study was made of 50 consecutive cases of left-sided congenital diaphragmatic hernia admitted to the Paediatric Surgical Unit of Southampton General Hospital over a 10-year period. All patients were treated by immediate surgical correction of the diaphragmatic defect and by conventional intensive post-operative management. We have found that it is possible to identify the stomach on plain radiographs of the chest and abdomen in the majority of patients.

In 42 cases the initial chest and abdominal radiographs were located and reviewed without knowledge of the operative findings, noting particularly the site of the stomach (intra-abdominal or intrathoracic) and the degree of mediastinal shift. In a further eight cases the radiographs could not be found.

The case notes of all 50 patients were reviewed, noting the operative findings with regard to the size of the diaphragmatic defect, the contents of the hernia and the position of the stomach. The final outcome was noted.

RESULTS

Table I shows the outcome related to the site of the stomach as determined at operation. The overall mortality was 42% (21 out of 50 infants). Of those with the stomach in the thorax, the mortality was 58.8% (20 out of 34 infants), but of those where the stomach was in the abdomen, the mortality was only 6.2% (one out of 16 infants) ($p < 0.005$).

At operation the stomach was found to be intra-abdominal in 16 patients and was associated in each case with small or medium-sized diaphragmatic defects. In 12 of these the stomach could be identified in the abdomen on the pre-operative radiograph. In the other four cases the left hemithorax was opaque in two, and in two the abdomen had not been included on the radiograph. The one death in this group was due to renal failure.

Of 34 patients proving to have an intrathoracic stomach at operation the pre-operative radiographs were available in 26. In all 26 the stomach could be radiologically identified in the chest. In the remaining eight cases the radiographs were not available, but the site of the stomach was identified at surgery. The majority of these cases (23) had large diaphragmatic defects at operation.

The degree of mediastinal displacement to the right was assessed on each radiograph. In 15 of the 16 "abdominal" cases and in 23 of the 24 "thoracic" cases it was severe, with marked compression of the right lung. There was no difference in this radiological feature between the two groups and the appearances did not correlate with the clinical severity of the condition (Figs 1, 2).

DISCUSSION

Two factors must be considered in the pathogenesis of congenital diaphragmatic hernia, namely the time at

TABLE I

OUTCOME RELATED TO THE SITE OF THE STOMACH AT OPERATION

Site of stomach	Outcome		Total
	Survived	Died	
Thorax	14	20	34
Abdomen	15	1	16
Total	29	21	50

which herniation occurred *in utero* and the mechanical effects of the bowel on the growing lung.

In the fetus rapid growth of the midgut occurs at about the eighth week, and the bowel herniates through the umbilicus, displaced by the developing liver. During this time the diaphragm is developing from a series of complex growths but it is not known which factors responsible for the failure of normal development result in a diaphragmatic hernia. The small gut returns to the abdomen at about the 10th week and it seems likely that the herniation into the chest occurs at this time. Rapid division of the bronchioles is also taking place, the bronchial tree normally being completely formed by 16 weeks. However, it appears that the herniating gut arrests development of the bronchioles, resulting in a reduced number of airways and subsequent pulmonary hypoplasia (Reid, 1984).

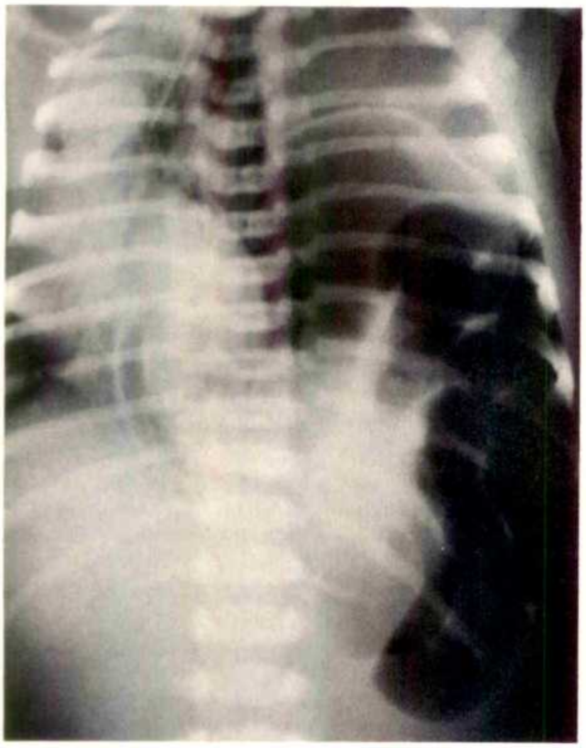


FIG. 1.

A chest radiograph of an infant with a left-sided diaphragmatic hernia showing the stomach to be in the thorax, with gross displacement of the mediastinum to the right.

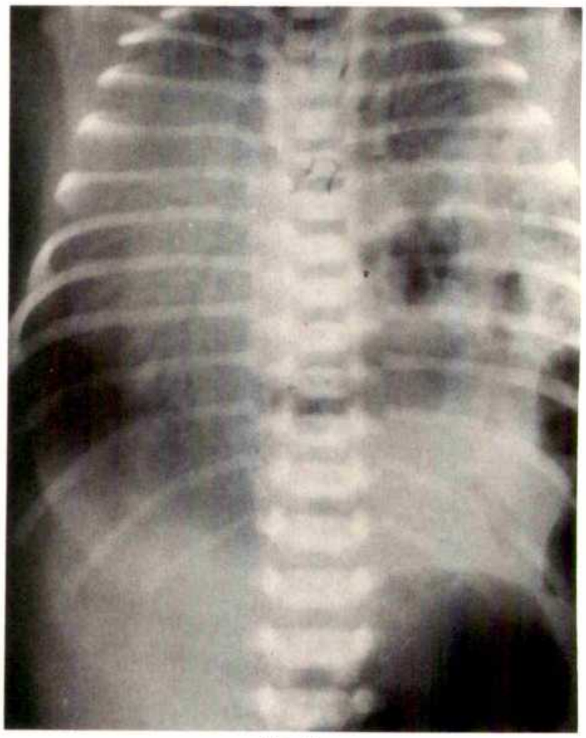


FIG. 2.

A chest radiograph of an infant with a left-sided diaphragmatic hernia and gross mediastinal shift, but with the stomach in the abdomen. (Film artefact is projected over D4.)

Minor changes in timing during this crucial period of rapid growth could have a significant effect on the resulting number of airways (de Lorimier et al, 1967). Early herniation would result in profound pulmonary hypoplasia, while slightly later herniation would result in only mild hypoplasia. No information is available on the associated development of the stomach at this time, although antenatal ultrasound studies may clarify this. It is possible that its final site is related to the timing of the herniation and to the size of the diaphragmatic defect. A large defect would allow early herniation with the stomach remaining in the chest. Consequently the stomach would act as a "marker" for the sequence of events and give an indication of the likely severity of the resulting pulmonary hypoplasia.

Insertion of inflatable balloons into the chests of fetal lambs during the last trimester of pregnancy results in significant pulmonary hypoplasia causing fatal pulmonary insufficiency in the neonatal period, the appearances being very similar to those seen in human congenital diaphragmatic hernia (Harrison et al, 1980a, b). Although bronchial-tree multiplication is complete by the 16th week of fetal life there is a considerable degree of growth and of development of the fetal alveolar units which normally takes place during the last trimester. It seems that the effect of mechanical compression is greatest during this period. However, the majority of our cases showed a severe degree of pulmonary compression associated with a marked shift of the mediastinum to the right side, whether the stomach was in the chest or the abdomen; yet the degree of pulmonary hypoplasia was clearly less in the latter group. This observation suggests that the timing of the herniation is more important than the mass effect in determining the severity of the pulmonary hypoplasia.

An early study classified infants with congenital diaphragmatic hernia into three prognostic groups based on the degree of pulmonary hypoplasia present (Berdon et al, 1968). However, it is now clear that the main prognostic feature in these infants is the degree of associated pulmonary vascular hypoplasia. *In utero*, the development of the pulmonary vessels closely follows the development of the bronchial tree and in diaphragmatic hernia both are hypoplastic. In the post-operative situation, a group of infants have fixed right-to-left arterial shunts with persisting hypoxia. These prove completely resistant to all efforts to improve pulmonary blood flow (non-responders). Their pulmonary vascular bed is simply inadequate to cope with the cardiac output. All of these infants die. A second group, despite significant pulmonary hypoplasia, appear to have a relatively normal pulmonary vascular capacity and resistance, although any stress may induce intense pulmonary vascular vasoconstriction with subsequent right-to-left shunting. These infants respond to treatment (responders), and chances of survival are significantly higher (Vacanti et al, 1984). A third group have minimal hypoplasia, often present late, and make an uneventful recovery following routine surgical repair.

From our own study it seems clear that the abdominal group of infants fall into the "responder" or "minimal hypoplasia" category. Although the initial radiograph may show the entire left chest to be filled with bowel with considerable associated shift of the mediastinum to the right, in fact the degree of pulmonary and vascular hypoplasia is less severe than might be expected and most of these children will survive. In the thoracic group the outlook is more serious, and many of these infants fall into the non-responder category. Radiographic demonstration of the site of the stomach in the abdomen or thorax is therefore a useful indicator of prognosis, and should alert the surgeon to the likely severity of the pulmonary abnormality and the possible post-operative complications. Passage of a fine nasogastric tube and injection of a little air immediately before the radiograph is taken will aid identification in difficult cases.

Prenatal ultrasonic diagnosis of diaphragmatic hernia has also proved possible. However, it is not clear whether or not the stomach can be accurately localised by this technique. This may have important implications, because to date the only prognostic feature in a fetus without any other chromosomal or structural abnormality is polyhydramnios (Nakayama et al, 1985). The demonstration of an intrathoracic stomach on a prenatal scan may indicate a poor prognosis and could be useful in determining which fetuses are suitable for antenatal surgical repair of the diaphragm.

REFERENCES

Berdon, W. E., Baker, D. H. & Armourey, R., 1968. The role of pulmonary hypoplasia in the prognosis of newborn infants with diaphragmatic hernia and eventration. *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine, 103*, 413–421.

Bloss, R. S., Turmen, T., Beardmore, H. E. & Aranda, J. V., 1980. Tolazoline therapy for persistent pulmonary hypertension after diaphragmatic repair. *Journal of Pediatrics, 97*, 984–988.

Bohn, D. J., James, I., Filler, R. M., Ein, S. H., Wesson, D. E., Shandling, B., Stephens, C. & Barker, G. A., 1984. The relationship between PaCO2 and ventilation parameters in predicting survival in congenital diaphragmatic hernia. *Journal of Pediatric Surgery, 19*, 666–671.

Boix-Ochoa, J., Peguero, G., Seijo, G., Natal, A. & Canals, J., 1974. Acid-base balance and blood gases in prognosis and therapy of congenital diaphragmatic hernia. *Journal of Pediatric Surgery, 9*, 49–57.

de Lorimier, A. A., Tierney, D. F. & Parker H. R., 1967. Hypoplastic lungs in fetal lambs, with surgically produced congenital diaphragmatic hernia. *Surgery, 62*, 12–17.

Harrison, M. R., Bressack, M. A., Chung, A. M. & de Lorimier, A. A., 1980a. Correction of congenital diaphragmatic hernia in utero. II. Simulated correction permits fetal lung growth with survival at birth. *Surgery, 88*, 260–268.

Harrison, M. R., Jester, J. A. & Ross, N. A., 1980b. Correction of congenital diaphragmatic hernia in utero. I. The model: intrathoracic balloon produces fatal pulmonary hypoplasia. *Surgery, 88*, 174–182.

Levin, D. L., 1978. Morphologic analysis of the pulmonary vascular bed in congenital left-sided diaphragmatic hernia. *Journal of Pediatrics, 92*, 805–809.

Naeye, R. L., Shochat, S. J., Whitman, V. & Maisels, M. J., 1976. Unsuspected pulmonary vascular abnormalities associated with diaphragmatic hernia. *Pediatrics, 58*, 902–906.

Nakayama, D. K., Harrison, M. R., Chinn, D. H., Callen, P. W., Filly, R. A., Golbus, M. S. & de Lorimier, A. A., 1985. Prenatal diagnosis and natural history of the fetus with a congenital diaphragmatic hernia: initial clinical experience. *Journal of Pediatric Surgery, 20*, 118–124.

Reid, L. M., 1984. Lung growth in health and disease. *British Journal of Diseases of the Chest, 78*, 113–134.

Simson, J. N. L. & Eckstein, H. B., 1985. Congenital diaphragmatic hernia: a 20 year experience. *British Journal of Surgery, 72*, 733–736.

Vacanti, J. P., Crone, R. K., Murphy, J. D., Smith, S. D., Black, P. R., Reid, L. M. & Hendren, W. H., 1984. The pulmonary haemodynamic response to perioperative anesthesia in the treatment of high-risk infants with congenital diaphragmatic hernia. *Journal of Pediatric Surgery, 19*, 672–679.

Book reviews

Notes on Radiological Diagnosis. By Lawrence S. W. Lau and John F. De Campo, pp. 204, 1985 (W. B. Saunders, Artarmon, Australia), £16.95.
ISBN 0-03-900275-6

This pocket-sized book is written by two Australian radiologists and is intended primarily for candidates preparing for the final diploma of the Royal Australian College of Radiologists. It is a book of lists presenting: (1) the findings of various conditions, (2) the differential of certain patterns, and (3) the approach to the investigation of certain clinical problems. Some of the lists included are not purely radiological but are related to pathology.

The first chapter is written as a guide to examination preparation and is of limited use to the British candidate. The chapters are then arranged by organ systems with a separate section for certain paediatric conditions. The lists are said to be arranged in order of frequency. This does not always reflect that found in practice in Great Britain. Some disorders which occur here relatively often do not appear at all, *e.g.* neither trauma nor sickle-cell disease are given as causes of a short metacarpal. The lists are simply stated, with little elaboration and some I felt could have been laid out in a better fashion and perhaps subdivided. I found the authors' use of abbreviations irritating. Some of them were not immediately obvious to me, but this may again reflect the Australian origins of the book (or simply my ignorance!).

Ultrasound, computed tomography and nuclear medicine are included which makes this text more complete than similar publications currently available and I liked the addition of some pathology and flow charts of suggested management which made the lists quite clinically orientated. I found the chapter on obstetrics and gynaecology particularly informative.

The book is rather expensive when compared with other available texts and the actual amount of information it contains is probably less although it does cover new topics and its approach is certainly thought-provoking. It would not be my first choice of currently available publications but would be a useful adjunct, easily afforded by departmental libraries.

Julie Wright

New Developments in Imaging. Ed. by R. Ch. Otto and C. B. Higgins, pp. x + 172, 1986 (Georg Thieme Verlag, Stuttgart), DM 98.
ISBN 3-13-697701-7 (Stuttgart)
0-86577-255-X (New York)

This book is based on the proceedings of a conference conducted on television via satellite between San Francisco and Zürich in December 1985. Those involved are mainly from San Francisco and Berlin, but there are contributions from a number of other US and German centres. The content is largely ultrasound (eight chapters) and magnetic resonance (five chapters), with two chapters on cine computed tomography (CT). Some of the chapters review a particular topic, while others report individual research studies.

There are three reviews of clinical magnetic resonance (MR) imaging, on the abdomen (Fiegler), the heart (Higgins) and the pelvis (Hricak). The abdominal chapter particularly is very succinct and would be difficult to follow without a preliminary knowledge of the subject. It is disconcerting to find T_1 values quoted with no mention of magnetic field strength, since T_1 varies with field strength. The cardiac review is good, but refers only to the US literature. There are two chapters on MR contrast agents: a review of the principles (Semmler) and a report of the use of gadolinium DTPA in renal neoplasm (Laniado).

Technical advances in cine CT are well reviewed by Magistri and colleagues and there is a good summary of the applications of the technique from the same group.

The ultrasound chapters contain a number of good reviews: advances in hepatobiliary and gastrointestinal imaging (Birnholz), ultrasound-guided biopsy (Otto), use of ultrasound in neurosurgery (Chandler) and echocardiography (Schiller). There are also reports on cardiac Doppler flow measurement (Redel), sonographic contrast medium (Fritzsch), endometrial appearances (Fleischer) and first-trimester ultrasound (Filly).

Although the book highlights a wide variety of new developments in imaging, it cannot be recommended as providing a comprehensive review of any of the major subject areas covered. This, together with its price, makes it difficult to recommend purchase to the individual radiologist in the UK. While it would be a useful addition to a radiology library, for the same reasons it cannot be recommended as a "must".

J. Webb

Teaching Atlas of Mammography, 2nd revised edit. By László Tabár and Peter B. Dean, pp. viii + 222, 1985 (Georg Thieme Verlag, Stuttgart), DM 168.
ISBN 3-13-640802-0 (Stuttgart)
0-86577-198-7 (New York)

A distinguished American radiologist once said "You only see what you look for, and you only recognise what you know". The stated aim of this atlas, in line with this philosophy, is to train radiologists in the perception and analysis of mammographic abnormalities and to reach a correct diagnosis through proper evaluation. Failure to apply these precepts is likely to bring screening mammography into disrepute because either small carcinomas are missed or the misinterpretation of benign conditions as malignancies leads to needless biopsy.

The illustrative material in the atlas includes mammograms where there were clinically overt abnormalities. However, the numerous examples where small and subtle findings were perceived only on screening mammography give this book a unique value. The illustrations are of high quality and are well annotated. A system of viewing is described which maximises the perception of mammographic abnormalities. The main thrust of the subsequent illustrative mammograms is to give practice in the recognition and evaluation of subtle radiological signs. Abnormalities are classified as circumscribed masses, stellate lesions and calcifications. These signs are put into anatomical and pathological context with the aid of succinct text and clear line drawings.

The preface to this second edition tells us that there is neither major revision nor additional figures to the first edition. However, the importance of this atlas is enhanced by the imminent inception of mammographic screening in the United Kingdom. Many radiologists will have to acquire new skills in mammographic interpretation. "Tabár and Dean" is unreservedly recommended as an aid to this learning process.

G. H. Whitehouse

1987, *The British Journal of Radiology*, *60*, 997–999 OCTOBER 1987

Position of the superior mesenteric artery on computed tomography and its relationship to retroperitoneal disease

By B. M. Carrington, M.R.C.P. and *D. F. Martin, M.R.C.P., F.R.C.R.

Department of Diagnostic Radiology, The Medical School, Stopford Building, Oxford Road, Manchester M13 9PT

(*Received February 1987*)

ABSTRACT

The superior mesenteric artery (SMA) is constant in its retroperitoneal course and easily identified on computed tomography (CT). In 225 CT examinations, anterior and lateral displacement from a defined normal position of the proximal SMA were assessed and correlated with the presence of retroperitoneal disease. Displacement beyond the left margin of the adjacent vertebral body was always due to disease, whereas an SMA situated to the right of a normal aorta was virtually always normal. Lesser degrees of displacement were not reliably associated with disease. In cases where there was minor SMA displacement but CT appeared normal, clinical follow-up revealed retroperitoneal disease in only three out of 40 patients (7.5%). Minor displacement of the SMA is not a good indicator of occult retroperitoneal disease.

The initial retroperitoneal portion of the superior mesenteric artery (SMA) occupies a constant position anterior to the aorta (Michels, 1955; Nebesar et al, 1969) and is easily seen on computed tomography (CT) (Moncada et al, 1979). The aim of this study was to test the hypothesis that SMA displacement alone might be an indicator of subtle retroperitoneal disease. This was assessed by categorising the position of the SMA, correlating it with visible retroperitoneal disease and obtaining clinical follow-up where the vessel was displaced by our criteria but the retroperitoneal appearances were normal.

MATERIALS AND METHODS

All CT examinations performed on patients with suspected upper abdominal disease during a 2-year period were reviewed.

Computed tomography was performed, with the patient supine, on an IGE CT/T 8800 scanner using constant radiographic factors and scan times. Contiguous sections 1 cm thick were obtained except in 20 cases where a 20 mm slice interval was used. Intravenous contrast medium (100 ml, 280 or 300 mg/ml iodine) was administered using a Medrad infusion pump at 2 ml/s in 195 patients.

Position of the SMA was categorised by devising a grid (Fig. 1). This was constructed by delineating three verticals, one from each lateral margin of the aorta and one from the left lateral border of the adjacent vertebral body and by drawing a horizontal line at a distance x in front of the vertebra, where x was the sagittal diameter of that vertebral body. There were eight possible positions for the SMA; Position 2 was defined as normal. Position was assessed for three contiguous scan slices at the level of the head of the pancreas. If the location of the SMA varied it was assigned to the position of maximum displacement.

Clinical details and disease visible on CT were correlated with the SMA position. In patients where the SMA was displaced with no obvious retroperitoneal disease, clinical follow-up was achieved by access to the notes or by questionnaire to determine whether any diagnosis had been made and by what means it had been obtained.

RESULTS

Of 244 patients eligible for the study, 19 were excluded: 10 because the region of interest was not included, five because the SMA was not adequately visualised and the remainder because assessment was impossible because of tortuosity of the aorta, a lumbar scoliosis or an extensive abdominal mass. Thus 225

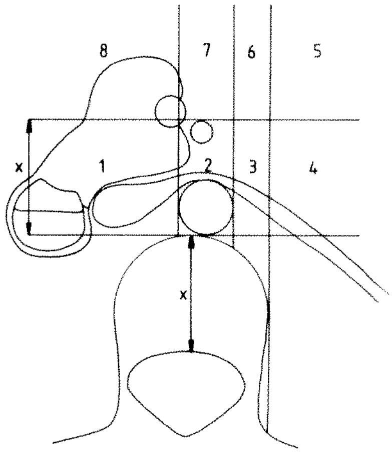


FIG. 1.

Grid to assess the position of the SMA (Positions 1–8), showing the superior mesenteric vessels immediately anterior to the confluence of the left renal vein and inferior vena cava, and the aorta.

---

*Author for correspondence.

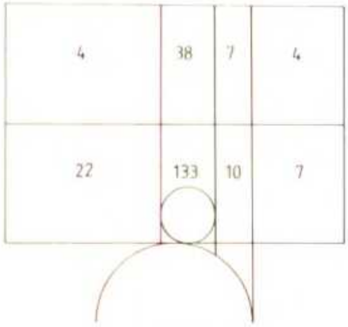


Fig. 2.

SMA position in all 225 patients.

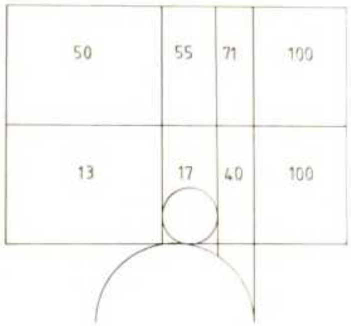


Fig. 4.

Final percentage in each position with retroperitoneal disease.

patients, 126 male and 99 female, were suitable for analysis. Their age range was 4–88 (mean 53.9) years, the majority being over 50 years (68.4%).

Figure 2 demonstrates the position of the SMA in all 225 examinations. One hundred and thirty-three patients (59.1%) had an SMA lying in our "normal" position and 92 had displaced vessels, most often in an anterior direction (53 patients, 23.5%). Figure 3 shows SMA position in the 66 patients with retroperitoneal disease visible on CT. With progressive displacement to the left and anteriorly, there is an increasing association with disease, such that all 11 patients with displacement beyond the left vertebral body margin had retroperitoneal disease. No equivalent observation was made regarding right-sided position.

Forty-nine patients (21.7%) had SMA displacement with no discernible disease on CT. Eight were excluded from follow-up because of a clinical explanation for the appearance, for example nephrectomy causing visceral rotation. Follow-up clinical information was obtained on 40 of the remaining 41 patients. The interval between the CT examination and follow-up varied between 4 and 28 months (mean 10.3 months). During this time three patients died and post-mortem examination had been performed on two; 10 had a laparotomy and one ultrasound-guided needle biopsy; five had undergone upper gastrointestinal endoscopy and seven endoscopic retrograde cholangiopancreatography (two with additional ultrasound); 15 patients had been reviewed clinically and biochemically, three of whom also had barium studies. As a result, retroperitoneal disease was found in only three of 40 cases (7.5%). One patient (Position 3) had peripancreatic lymphadenopathy not evident on CT. In two patients with anterior displacement alone (Position 7), one had pancreatic metastases from a bronchial carcinoma found at autopsy and the other had an inflammatory mass in the head and uncinate process of the pancreas discovered at laparotomy. The final percentage of patients with each SMA position with retroperitoneal disease is shown in Fig. 4.

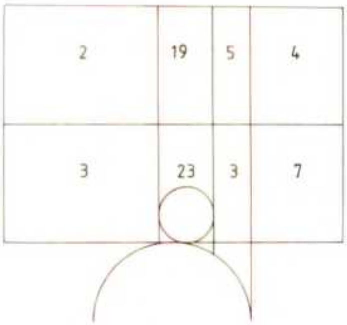


Fig. 3.

SMA position in 66 patients with retroperitoneal disease on CT.

Discussion

The SMA is easily recognisable on CT and has been visualised on 89% of non-contrast-enhanced scans (Kolmannskog et al, 1982). In this study it was seen in 98% of contrast-enhanced scans.

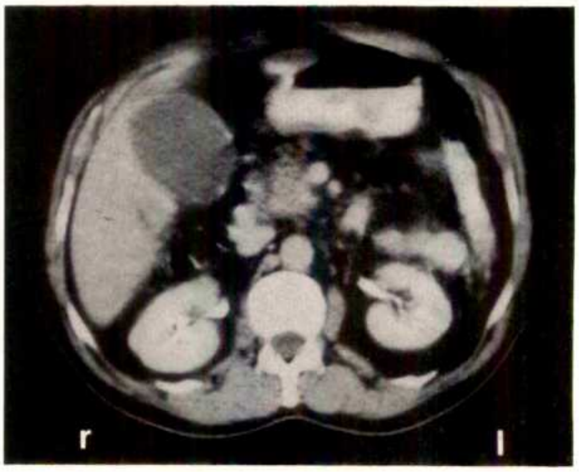


Fig. 5.

Carcinoma of the uncinate process causing SMA displacement beyond the left vertebral body margin.

Vessel displacement to the left of the vertebral body was always associated with retroperitoneal disease evident on CT and therefore may be a useful additional sign in suspected cases (Fig. 5). An SMA situated to the right of the aorta was not commonly associated with retroperitoneal disease. Only five of 26 such patients had any abnormality and four had an aortic aneurysm. At follow-up no patient in this group was found to have retroperitoneal disease. Therefore, if the SMA is situated to the right of a non-aneurysmal aorta, this can be considered normal.

Only three of 40 patients (7.5%) had retroperitoneal disease discovered at follow-up. Therefore minor SMA displacement alone is not a useful indicator of disease. Conversely, the SMA may not be displaced even in the presence of significant disease; 23 patients had retroperitoneal abnormalities visible on CT but the SMA remained in a normal position.

Displacement of the SMA beyond the left vertebral body margin is a good indicator of retroperitoneal disease, which should always be visible on CT. However, minor alterations in position are often normal and, when found in isolation, cannot be used as a marker for retroperitoneal disease.

Acknowledgment

The authors would like to thank Mrs Anne Schofield for typing the manuscript.

REFERENCES

Kolmannskog, F., Swenson, T., Vatn, M. H. & Larsen, S., 1982. Computed tomography and ultrasound of the normal pancreas. *Acta Radiologica Diagnosis*, *23*, 443–451.

Michels, N. A., 1955. *Blood Supply and Anatomy of the Upper Abdominal Organs: a Descriptive Atlas*. (Pitman Medical Publishing London), pp. 280–293.

Moncada, R., Reynes, C., Churchill, R. & Love, L., 1979. Normal vascular anatomy of the abdomen on computed tomography. *Radiological Clinics of North America*, *17*, 25–37.

Nebesar, R. A., Kornbluth, P. L., Pollard, J. J. & Michels, N. A., 1969. *Celiac and Mesenteric Arteries: a Correlation of Angiograms and Dissections*. (J. & A. Churchill, London.)

Book reviews

Herbert M. Parker: Publications and Other Contributions to Radiological and Health Physics. Ed. by R. L. Kathren, R. W. Baalman and W. J. Bair, pp. xxiv + 822, 1986 (Baltelle Press, Columbus, Ohio), $55.00.
ISBN 0-935470-36-0

Herbert M. Parker was one of the founders of medical and health physics. During a mere 6 years in Manchester, he, with Ralston Paterson, changed the face of radium therapy, devising the system still in use over 50 years later. After a few years in Seattle, working mainly on 800 kV X-ray therapy, he joined the Manhattan District (code name for the development of the atomic bomb) in 1942 and his career took a new direction. Henceforth he was to be primarily concerned with a radiation safety programme of immense scope and complexity and to become one of its guiding stars. From having in his earlier years produced a steady stream of papers, now most of his work was to be recorded in "restricted" documents or in more anonymous publications such as the reports of the National Council on Radiation Protection and Measurements. Therefore three close friends and colleagues resolved to collect together as much of his writing as possible and publish it in a memorial volume. Hence this handsome book which, however, because of its length (over 800 pages, often of quite small type) and the diversity of its subject matter, is not easy to review succintly.

It opens with a survey of Parker's career and achievements and is then divided into five main sections dealing respectively with the Manchester years, medical physics after Manchester, contributions in the evolution of radiological units, radiation protection and radioactive waste management. A delightful feature of the book is that the section-dividing pages are reproductions of pages from a notebook kept by Parker in his Manchester days. The precision and clarity of these records are models which all would do well to copy and they are most evocative to one who knew them, and their author, so well.

The constituent papers cover a considerable range of both time and topic: from 1934 to 1983; from the original dosage system through rep and rem and tolerance doses to radioactive-waste management; from the amusing to the amazing and, at times, the boring though never the trivial. Not all of the inclusions are successful. For example, some of the originally "classified" typescript reports are difficult to decipher, and are not always worth the effort! The reports of Parker's evidence to Congress committees would be more easily understood had a glossary been provided to interpret the acronyms and initials with which they are sprinkled, while his obviously very cogent critique of a report by Robley Evans cannot be fully appreciated since it refers to diagrams and tables in the paper under review but not available to the present reader. There are also several examples of complete repetitions, the elimination of which would have detracted nothing from the volume, except weight. Particularly unfortunate is the presentation of two almost identical versions of the first radium dosage paper, which may have been a mistake since the fundamental and unique paper on interstitial radium treatments (Parker at his mathematical greatest) is omitted altogether.

But there are compensating treasures and not only among the established classics. For example, there is a paper (with Simeon Cantril) giving a detailed description of the meticulous protective measures provided at Hanford. Written the day after the bomb was dropped on Hiroshima and intended to reassure the Hanford workers, it was held up for 2 years by "Security"! Or an early paper on the potential hazards of excessive paediatric radiology, or some excellent surveys of dosimetry and "the tolerance dose" which could still be taken over almost verbatim by anyone teaching the subject. On a lighter level there are descriptions of dealing with "the problem of getting data when one cannot reveal any interest in radiation", which necessitated clandestine trips into the countryside for vegetation samples or Parker's apparent fussiness, during a bowling match, in choosing a different ball each turn and "fastidiously wiping the finger holes with Kleenex, thus acquiring a fine collection of wipe samples to test whether hand contamination was detectable in the public domain".

This is a very well produced and presented volume and, for its size, it is not expensive. But it is difficult to see it having a wide readership. Most of the major contributions, and there are a goodly number, are well known and have already been assimilated into textbooks or official recommendations and regulations. Its chief value will probably be to anyone interested in the history of health physics and especially in the background to the development of protection standards or dosage units and measurements. Undoubtedly it is a worthy memorial to a very considerable scientist. Unfortunately, memorials tend to get overlooked and dusty and perhaps, as is written in St Paul's Cathedral of Sir Christopher Wren ("If you would see his monument, look around"), so of Parker one can say "Look at the radium dosage system and the safety standards".

W. J. MEREDITH

Radiology of Lymphomas. Ed. by J.-N. Bruneton and M. Schneider, pp. xii + 144, 1986 (Springer-Verlag, Berlin), DM 124.
ISBN 3-540-15951-7 (Berlin)
0-387-15951-7 (New York)

It is probably true that too few radiologists, particularly those in training, raise the spectre of lymphoma in their differential diagnoses. The multisystem nature of lymphoma and the lack of characteristic radiological features are well known: lymphoma appears at the bottom of innumerable lists of differential diagnoses spanning all systems of the body. The detection and staging of lymphomatous diseases has become increasingly successful and precise with the development of sophisticated imaging. The publication of a book devoted to the radiology of lymphomas is most timely.

It is a relatively small book, of only 115 pages, but it is, nevertheless, generously illustrated. For clarity, the editors have sensibly chosen to discuss lymphoma in terms of anatomical site rather than histological type. Each chapter contains a discussion of the imaging methods available and includes an extensive review of the literature. The references are almost too numerous: the 115 pages of text are followed by a further 21 pages of references. There is particular emphasis on figures relating to incidence and survival rates. Sadly, the marked discrepancy between many of the figures quoted from various series detracts from the usefulness of this information.

In the main, continuity of style throughout the book has been maintained by the editors. The exception to this is the short chapter on orbital lymphoma which consists, almost entirely, of a recital of clinical and computed tomographic findings in individual cases with no cohesive review of the subject. Overall, this book is logically presented and it surveys comprehensively all the radiological manifestations of lymphoma and the sequelae following treatment. Given the wide-ranging presentations of lymphoma, which may be detected by so many imaging techniques, this book is recommended for any departmental library, providing the necessary deutschmarks can be found.

D. M. KING

1987, *The British Journal of Radiology*, *60*, 1001–1009

OCTOBER 1987

A set of X-ray test objects for image quality control in digital subtraction fluorography. I: design considerations

By A. R. Cowen, B.Sc., J. M. Haywood, T.Eng.(C.E.I.), A. Workman, M.Sc. and O. F. Clarke, T.Eng.(C.E.I.)

The University of Leeds, Department of Medical Physics, The General Infirmary, Leeds LS1 3EX

(*Received November 1986 and in revised form February 1987*)

ABSTRACT

A set of X-ray test objects has been developed for quality control in digital subtraction fluorography (DSF). Factors which can be assessed include dynamic range, highlight overload and signal-to-noise ratio, low contrast sensitivity, unsharpness, and systematic misregistration. These test objects complement, both in design and calibration, those previously developed to evaluate the imaging performance of television fluoroscopy and small-format fluorography systems. In this article, the first of two, we describe the Leeds DSF test objects, paying particular attention to the reasoning behind their design.

The increasing cost and technical sophistication of modern radiological imaging equipment has led to a greater awareness among scientific and clinical staff involved in diagnostic radiology of the need for quality control. Various test objects and phantoms have been produced to monitor the performance of conventional radiological imaging equipment (*e.g.* Hay et al, 1985). In the United Kingdom, bodies such as the Supplies Technology Division of the Department of Health and Social Security (DHSS) and the Hospital Physicists' Association (HPA) (Diagnostic Radiology Topic Group) have taken a useful lead in recommending particular quality-control test procedures (DHSS, 1982; HPA, 1983). This has encouraged standardisation of equipment testing, which in turn has led to a greater degree of understanding between the various parties involved in equipment installation, acceptance testing and quality control.

The introduction of computer-based radiological imaging equipment such as digital subtraction fluorography (DSF) systems has posed new challenges to the quality-control scientist. Few of the quality-control techniques previously developed to assess conventional equipment have the sensitivity needed to assess digital X-ray imaging systems rigorously. Specialised DSF test phantoms and quality-control procedures have been developed by several groups in the United States of America (American Association of Physics in Medicine (AAPM), 1985). Our involvement with the installation and acceptance testing of a DSF system in the General Infirmary at Leeds gave us the opportunity to develop a rigorous test procedure with which to monitor its imaging performance and identify and correct any misadjustments which might occur (Cowen et al, 1985). Further to these experiences we have produced a set of Leeds DSF test objects which complements the Leeds test objects designed to test television fluoroscopy and small-format fluorography systems (Hay et al, 1985). The Leeds DSF test objects have several features in common with the conventional Leeds test objects. For example, the new test objects are constructed from analytical-quality metal (aluminium, copper and lead) foils mounted in Perspex containers. These containers have a laminar construction in order to minimise the effects of X-ray scatter and the contribution of focal-spot unsharpness when they are positioned adjacent to the input window of the X-ray image intensifier. The DSF test-object set comprises four separate devices each of which is designed to evaluate specific aspects of DSF imaging performance.

This article describes the Leeds DSF test objects and outlines their design considerations. The use of the test objects and the interpretation of results obtained are dealt with in the second paper (this issue of *BJR*, following paper).

IMAGING EQUIPMENT

The initial development of the Leeds DSF test objects was carried out using the Philips single-plane angiography installation at the General Infirmary at Leeds. This equipment comprised an Optimus M200 X-ray generator, a 0.3/0.7 mm focus metal X-ray tube, a 14 in X-ray image intensifier and a Plumbicon XTV-6 television chain operating in combination with a DVI-V digital vascular subtraction system. Subsequently, this equipment has been updated to the DVI-CV version. Throughout these articles this equipment will be referred to as "the reference system". Detailed digital videodensitometric calibration of the test objects was carried out with the aid of an analytical processing unit. Test images were viewed on a high-quality video display unit (Bosch Fernseh Display Monitor type M38 BA). Hard-copy images were recorded using a Matrix Instruments MI-7 multiformat camera: the MRF 31 film was processed in a Kodak RP X-omat Model M6A-L rapid processor.

DYNAMIC RANGE AND CLINICAL IMAGING PERFORMANCE

The fundamental physical imaging characteristic of a DSF system is its dynamic range, viz. the range of X-

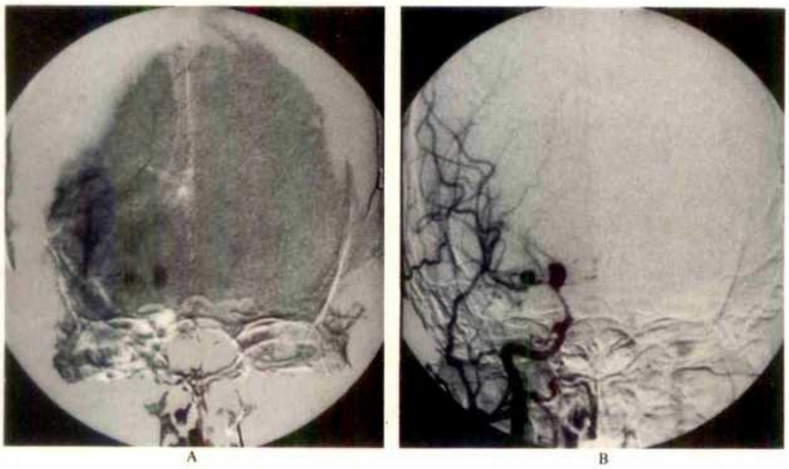


Fig. 1.

(A) DSF image of the skull using an 80% video peak level resulting in severe highlight overload around the periphery of the image field. (B) Alleviation of highlight overload using a reduced video peak level of 40%.

ray intensities over which effective background subtraction and signal detail reproduction take place. The range of X-ray intensities which a DSF system has to accommodate obviously depends upon the anatomy in the region of interest and the choice of X-ray tube voltage, imaging geometry and the degree of collimation and scatter suppression. Technical factors which influence dynamic range include the maximum signal-current capability of the television-camera tube, the X-ray exposure per image frame and the power of the camera pre-amplifier noise. In order to maximise the video signal amplitude, the television-camera tube is usually operated in a boosted beam-current condition. Other system features which influence dynamic range include the match between the video modulation levels and the digital processor (both at the input and output stages) and, in certain designs of equipment, the presence of coarse video-processing stages such as black-level clipping and peak white limiting circuits.

Many DSF devices operate using peak-sensing of the video signal to control the adjustment of the radiographic exposure factors. In the case of the reference system, exposure factors are automatically adjusted to set the peak video signal, within an active window, to a value approximately 80% of the analogue–digital converter range (Winkels, 1986). This leaves a safety margin, often referred to as the "operating headroom", of approximately 20% at the top of the video range which is used to accommodate highlight regions lying outside the active window. Other types of DSF system use automatic peak-sensing to levels greater than 80%; differing levels up to 99% of the video range are used by the various designs. In some other designs the system is operated manually, whereby the video peak is set at the discretion of the operator. Reducing the operating headroom increases the technical dynamic range but makes the system more susceptible to operating difficulties. On the other hand, increasing the operating headroom can improve equipment operation but can lead to reduced image quality.

Regions of highlight overload (saturation of the camera target or the analogue–digital converter) manifest themselves as homogeneous grey patches in the subtracted image (Fig. 1A). If these patches encroach upon regions of diagnostic significance the clinical examination may be seriously compromised. The method most commonly used to alleviate problems of highlight overload is to place bolus material in the X-ray beam to equalise the distribution of X-ray intensity (Facility for Assessment of X-ray Imaging at Leeds (FAXIL), 1986). Positioning the bolus material by hand can result in unnecessary radiation exposure of the patient and clinical staff. Rouse et al (1984) have shown that for certain clinical examinations it is possible to dispense with bolus material but still alleviate highlight overload problems by reducing the video peak to levels as low as 40% (Fig. 1B). This technique reduces the technical dynamic range available and therefore demands a high level of basic system performance.

Our experiences with many DSF systems led us to appreciate that susceptibility to highlight overload can have serious consequences for the imaging performance and clinical effectiveness of DSF. We have therefore developed a test object (known as the jig test object TO.J3) specifically to test the calibration and the reproducibility of this factor. It should be noted that this test object has not been designed to assess systems which operate by average-signal sensing of the automatic exposure control. The test object can be used, however, to check performance reproducibility of such systems on a routine basis provided great care is taken in interpreting the results. The jig test object comprises a fixed base-plate and a rotatable top-plate. Both plates are divided into four sectors upon which are positioned relevant test details. Two of the sectors of the top-plate are denoted "test sectors" and contain the assessment information and the other two are denoted

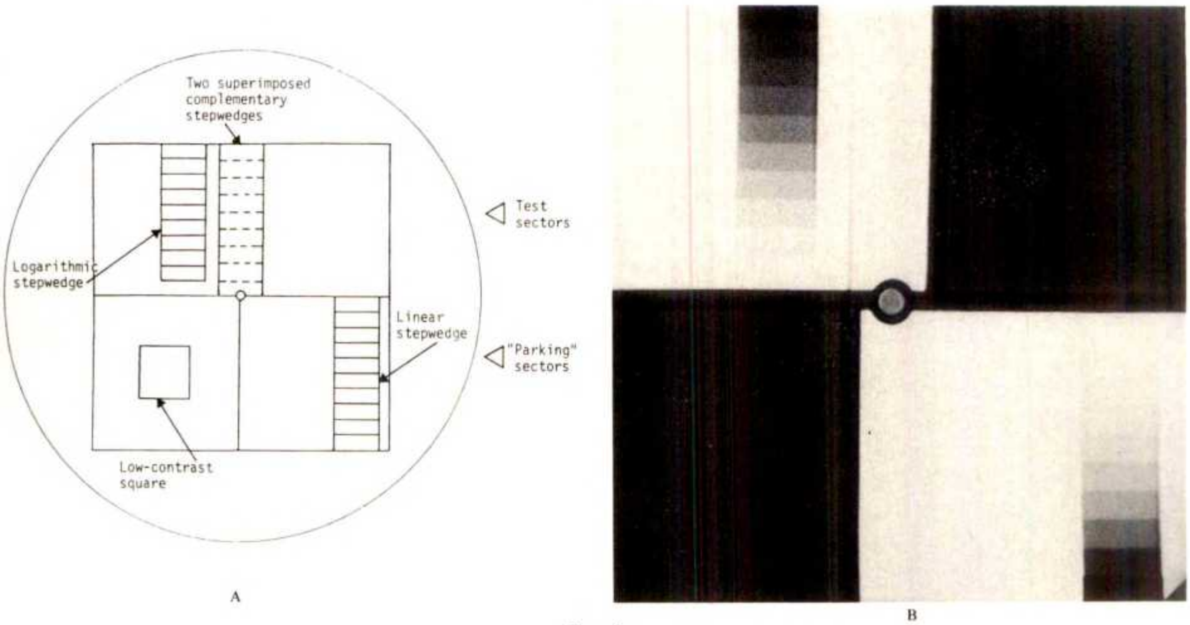


FIG. 2.

(A) Schematic diagram of a mask image of the "jig" test object. (B) Hard-copy image of a mask exposure of the "jig" test object.

"parking sectors". Separate test sectors are provided to assess the highlight and lowlight extremes of the dynamic range. The initial mask image is formed with the test object arranged such that the peak video signal is referred to the test sector which exhibits the greatest X-ray transmission (the top left highlight test sector). A schematic diagram and hard-copy image of TO.J3 in the mask condition are presented in Fig. 2A, B. The

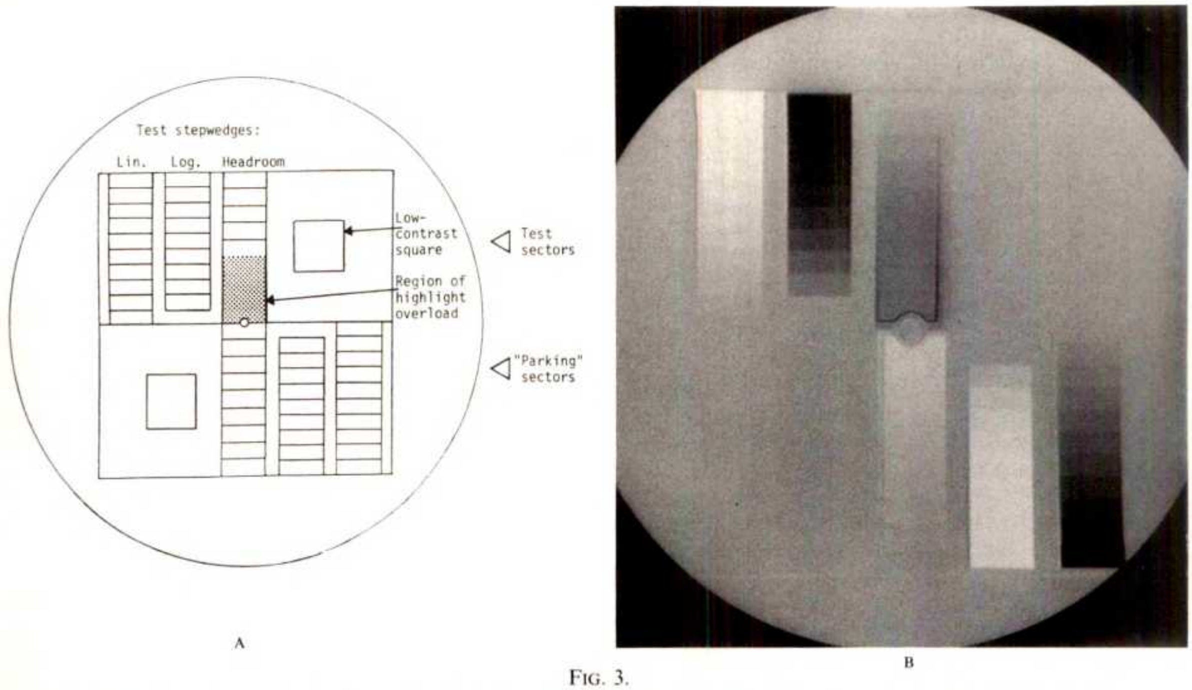


FIG. 3.

(A) Schematic diagram of a DSF image of the "jig" test object. (B) Hard-copy of a DSF image of the "jig" test object.

highlight test sector comprises a homogeneous 0.5 mm-thick copper plate. This sector also contains two equivalent step-wedges, one fixed to the base-plate, the other to the top-plate, arranged one on top of the other in a complementary manner such that their thicknesses add up to a constant reference filter thickness (0.5 mm copper). Following the mask exposure and prior to the test exposure the image content is changed by rotating the top-plate through 180° with respect to the base-plate. This removes one of the two complementary step-wedges from the highlight sector and repositions it in the appropriate parking sector. This test exposure generates a set of nine discrete X-ray intensity levels which progressively exceed the peak reference level. This feature of the test object is used to assess the calibration and reproducibility of the operating head-room. A schematic diagram of the test object following digital subtraction is presented in Fig. 3A with a DSF hard-copy image in Fig. 3B.

It will be seen from the mask image, Fig. 2B, that TO.J3 contains two other high-contrast test wedges, one positioned in the highlight test sector and the other in the bottom right parking sector. Following rotation of the top-plate of the jig, these step-wedges exchange sectors to produce two high-contrast step-wedges in the highlight test sector. Under calibrated beam conditions these step-wedges produce approximately linear DSF signal levels following linear and logarithmic subtraction (each step-wedge encompasses approximately one order of magnitude in DSF signal). The step-wedges were calibrated under scatter-free imaging conditions. They are used to check the reproducibility of linear and logarithmic digital subtraction processes.

The lower limit of a DSF system's dynamic range is a statistical barrier set by the power of the electronic noise. In order to monitor the power of the noise the lowlight test sector (top right) of the subtraction image contains a 0.025 mm-thick low-contrast copper plate situated upon a 2 mm-thick copper filter which attenuates the X-ray intensity to a level where electronic noise influences imaging performance.

Dynamic Range and Signal-to-Noise Ratio

Manufacturers of DSF equipment normally specify the dynamic range in terms of the signal-to-noise ratio of the television-camera tube. Values of signal-to-noise ratio exceeding 50 dB and even 60 dB have been claimed. It is difficult to relate this physical factor directly to the level of imaging performance produced in clinical practice (Verhoeven, 1985). Experience in the field has shown that, provided measures are taken to limit the range of X-ray intensities, it is possible to carry out DSF very successfully with equipment of comparatively modest technical specification (FAXIL, 1986). Furthermore, as it is difficult to measure this factor accurately in the field, it is of limited value in quality-control testing. For DSF systems which incorporate an analytical computing facility it may be possible to assess the signal-to-noise ratio of the DSF process on a regular basis using a test routine which calculates the relative standard deviation of the noise from images produced under standard exposure conditions (Arnold & Scheibe, 1984).

Kruger et al (1981) presented a description of the signal-to-noise ratio processes in DSF imaging. This analysis can be extended to include other physical processes which influence the dynamic range, thereby providing a wider basis for interpreting DSF imaging performance.

Under scatter-free imaging conditions the signal-to-noise ratio (SNR) of the DSF process at different levels throughout the dynamic range can be described by the relation:

$$\mathrm{SNR}(L_{\mathrm{X}}) = \frac{L_{\mathrm{X}}}{\sqrt{2}\left\{\dfrac{L_{\mathrm{X}}}{X_{\mathrm{f}}^{\max} R\eta a m} + \dfrac{1}{m}\left[\dfrac{1}{\mathrm{SNR}_{\mathrm{TV}}^{2}}\right] + \left[\dfrac{\Phi_{\mathrm{d}}}{m} + \dfrac{\Phi_{\mathrm{D}}}{2\gamma_{\mathrm{D}}^{2}}\right] L_{\mathrm{X}}^{2}\right\}^{\frac{1}{2}}} \qquad (1)$$

where

L_x is the level within the dynamic range ($i.e.\ \frac{X_{\mathrm{f}}}{X_{\mathrm{f}}^{\max}}$)

X_{f} is the input exposure level

$X_{\mathrm{f}}^{\max}$ is the input exposure level corresponding to the peak video signal

a is the area of one pixel (it is assumed that the limiting unsharpness occurs after the point where electronic noise is introduced)

R is a conversion ratio expressing the relationship between quantum flux density and exposure

η is the detective quantum efficiency of the X-ray image intensifier

m is the number of television frames integrated

Φ_{d} is the power of noise associated with the (grey-scale) digitisation process

Φ_{D} is the power of the noise introduced by the display process including the internal noise of the observer

γ_{D} is the gamma (contrast amplification factor) of the display process

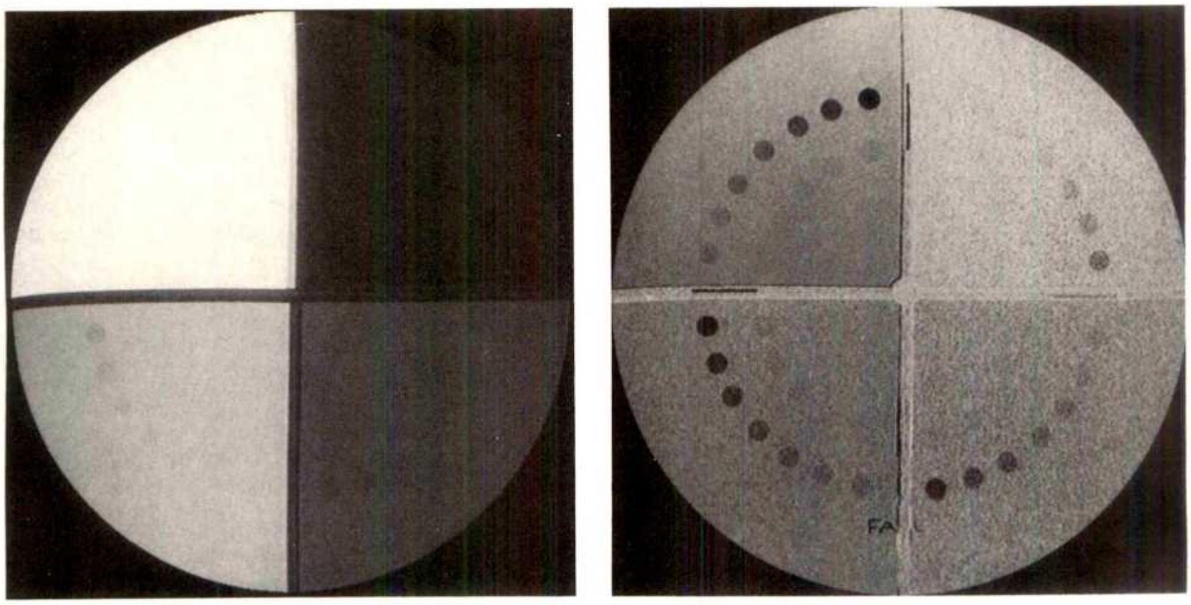
$\mathrm{SNR}_{\mathrm{TV}}$ is the signal-to-noise ratio of the television system where,

$$\mathrm{SNR}_{\mathrm{TV}} = \left[\frac{X_{\mathrm{f}}^{\max} G}{\sigma_{\mathrm{TV}}}\right] \qquad (2)$$

G is the gain factor relating radiation exposure and video signal amplitude (including the effect of the iris aperture)

σ_{TV}^{2} is the power of the television camera pre-amplifier noise

Equation 1 provides a useful insight into the dynamic range and signal-to-noise ratio of the DSF imaging process. As the noise in the mask and test images are statistically uncorrelated, the noise power in the



A

B

FIG. 4.

(A) Mask image of the four-sector "quadrant" dynamic range test object. (B) DSF image of the four-sector "quadrant" dynamic range test object.

subtracted image is increased by a factor of two. The DSF signal-to-noise ratio is a function of the four noise processes (viz. X-ray quantum noise, TV camera noise, digitisation noise and display process noise). Digital subtraction fluorography systems which store their images in analogue form, either on videotape or videodisc, are subject to additional electronic noise (Riederer et al, 1981). In efficient radiological imaging the fundamental source of noise arises from X-ray quantum statistics; this should also be the dominating noise process in regions of the DSF image produced at high radiation intensities (*i.e.* as $X_f \rightarrow X_f^{\max}$ or $L_x \rightarrow$ unity). At very high levels of exposure per image frame, residual noise due to the digitisation process and/or the effect of television scan instabilities dominate the signal-to-noise ratio. The former arises from the statistics of digitally sampling inherently random signals (Kruger et al, 1981) and instabilities in the analogue–digital and digital–analogue conversion processes. The latter (raster instabilities) result in imperfect subtraction of system structure noise (Arnold

TABLE I

PERFORMANCE FEATURES TESTED

Test object	Features addressed
Jig TO.J3	Log/linear subtraction Operating headroom Power of electronic noise
Quadrant TO.Q3	Dynamic range of imaging system
TO.20	Threshold contrast detail detectability
Dalmatian TO.D3	Systematic misregistration artefacts

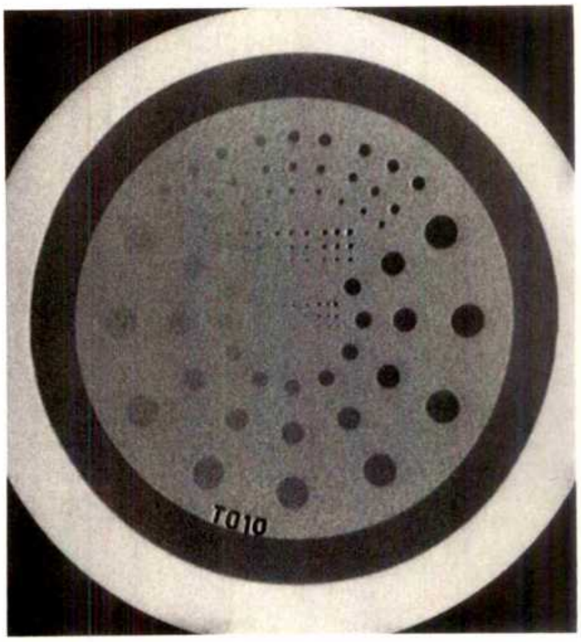


FIG. 5.

DSF image of the conventional Leeds TCDD test object type TO.10.

& Scheibe, 1984). Analogue noise also arises in the image display devices and within the visual system of the human observer. The contrast amplification factor (gamma) of the displayed image is usually adjusted to minimise the contribution of internal visual noise. Noise introduced by a poor-quality or badly adjusted video camera unit can severely degrade the quality of hard-copy images. This noise arises from irregularities in the raster structure, the granularity of the phosphor screen, dust and dirt on the optics and film processing artefacts.

In regions of the image corresponding to low levels of radiation intensity the electronic noise dominates and the signal-to-noise ratio of the DSF process is given by:

$$\mathrm{SNR} \rightarrow \frac{L_X m^{\frac{1}{2}}}{\sqrt{2}\left[\dfrac{1}{\mathrm{SNR}_{\mathrm{TV}}}\right]} \tag{3}$$

as $L_X \rightarrow 0$.

Under these circumstances, the signal-to-noise ratio of the DSF process decreases linearly with the intensity of the radiation beam; the power of the electronic noise remains constant.

A practical indication of operating dynamic range can be obtained by subjectively assessing the range of X-ray intensities over which the DSF system successfully reproduces details of low subject contrast. For the purposes of quality control this is achieved using a Leeds quadrant test object (TO.Q3). This device comprises four copper filters of different thickness which produce a range of calibrated X-ray intensities at the input to the X-ray image intensifier. Under calibrated beam conditions the approximate X-ray transmissions of the four sectors of the test object follow the ratios 1 : 0.33 : 0.10 : 0.033. It should be noted that this input dynamic range will be reduced by contrast-loss effects in the X-ray image intensifier tube. Superimposed on each of the segments are identical sets of 16 circular details, 8 mm in diameter and of estimated X-ray contrast range varying between 20% and 0.1%. The effectiveness of the subtraction process can be evaluated subjectively in terms of the minimum contrast visible in each of the four test sectors. Mask and digital subtraction images of the TO.Q3 are presented in Fig. 4A, B.

Low Contrast Sensitivity in DSF Imaging

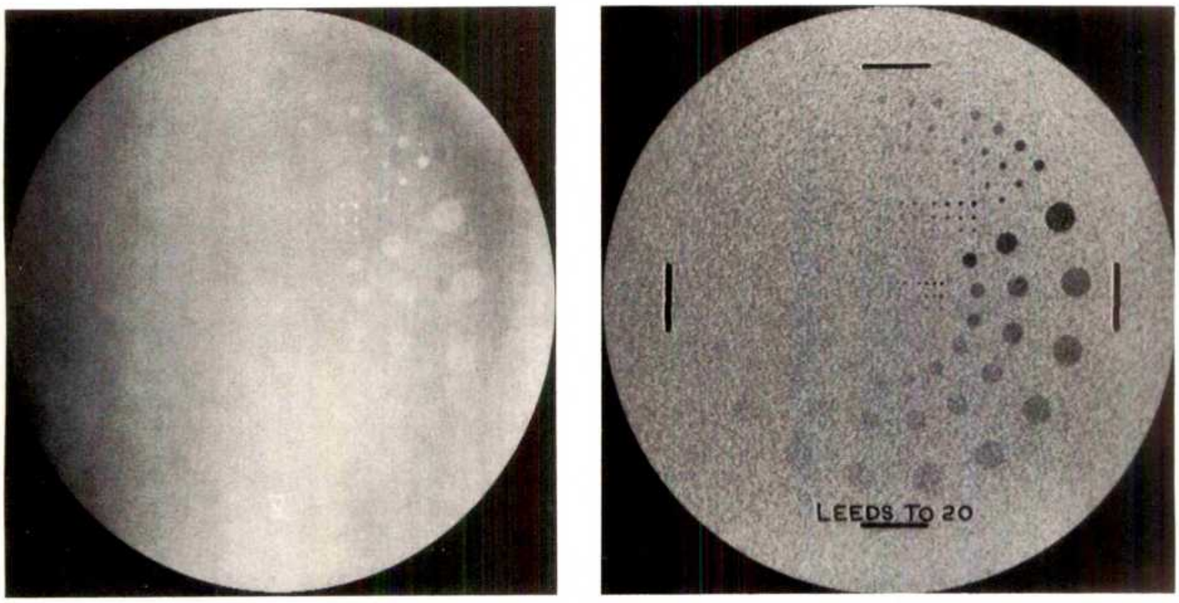
In order to carry out successful intravenous or low-contrast strength intra-arterial DSA it is essential that the imaging equipment produces very good low-contrast sensitivity. Therefore a DSF quality-control procedure must provide a method of testing low-contrast performance. As DSF systems have been designed to image iodinated contrast agents, Riederer et al (1981) have suggested that the minimum concentration of iodine which can be detected visually should be used to assess the contrast sensitivity of DSF systems. A variety of iodine-based test phantoms (which can be used to simulate clinical conditions) are now commercially available (FAXIL, 1985). In order to assess the efficacy of such devices we have manufactured an iodine-based test phantom of our own design following the procedure of Riederer et al (1981). Our experiences indicate that the iodine-based test phantom is comparatively insensitive as a quality-control tool and is difficult to calibrate to high accuracy, particularly at low concentrations of iodine (Cowen et al, 1985). Furthermore, we would envisage that it would be difficult to fabricate large numbers of these test phantoms with a high degree of reproducibility.

The threshold-contrast detail-detectability (TCDD) test has proved a useful method of assessing the low contrast sensitivity of conventional radiological imaging systems (Hay et al, 1985). The method has proved successful both in laboratory performance evaluation and under field conditions for quality control. The method is based upon TCDD test objects which comprise an array of disc-shaped metal details of varying (and calibrated) diameter and X-ray contrast. The test objects are attached to the input of the imaging system and images are formed under specified radiographic exposure conditions. The laminar form of the test objects ensures negligible contributions from scattered radiation and focal-spot unsharpness. The resulting images are examined by two (or more) experienced observers who determine the minimum (threshold) contrast at each detail diameter. Carefully controlled viewing conditions are required. An advantage of the TCDD technique is that in the assessment the objective characteristics of the images are naturally weighted by the visual mechanisms of a human observer. A DSF image of the current standard Leeds TCDD test object type TO.10 is presented in Fig. 5. This device was designed to assess the imaging performance of television fluoroscopy and small-format fluorography systems. The range of detail contrasts provided with TO.10 are clearly inadequate to address the contrast sensitivity of a well adjusted modern DSF system as almost all the details are suprathreshold. In order to evaluate DSF systems it has therefore proved necessary to develop a test object specifically matched to the imaging performance of these systems. A test object has been developed which can evaluate systems which exhibit a 10-fold greater contrast sensitivity than conventional X-ray fluoroscopy equipment. This test object is referred to as TO.20*V*.

Mask and digital subtraction images of TO.20*V* are presented in Fig. 6A, B. The improvement in low-contrast sensitivity produced by digital subtraction is clearly visible in the increased number of low-contrast details which are perceptible.

Under X-ray quantum limited conditions, the signal-to-noise ratio measured over a detail of area A in a DSF image can be described by the relation:

$$\Delta\mathrm{SNR}(A) = \frac{\Delta S\left(\dfrac{A}{a}\right)^{\frac{1}{2}}}{[\mathrm{SNR}^{-1}]} \tag{4}$$



A B

FIG. 6.

(A) Mask image of Leeds DSF TCDD test object type TO.20$\bar{V}$. (B) Digital subtraction image of Leeds DSF TCDD test object type TO.20$\bar{V}$.

i.e.

$$\Delta\mathrm{SNR}(A,X_{\mathrm{f}}^{\max}) = \frac{\Delta S\left(\frac{A}{a}\right)^{\frac{1}{2}}}{\sqrt{2}[X_{\mathrm{f}}^{\max} R\eta am]^{-\frac{1}{2}}} \quad (5)$$

where ΔS is the signal detail and SNR is the quantum-limited signal-to-noise ratio. We assume that the detail signal-to-noise ratio (ΔSNR) is determined by integrating the signal detail and noise over an area A (where $A \gg a$).

The threshold low-contrast detectability of a human observer examining such a DSF image can be described by the relation:

$$\Delta\mathrm{SNR}(A,X_{\mathrm{f}}^{\max}) \approx k_{\mathrm{T}}$$

and therefore the threshold contrast is defined by:

$$\Delta S_{\mathrm{T}}(A) \approx k_{\mathrm{T}} \frac{\sqrt{2}}{[X_{\mathrm{f}}^{\max}\eta\, RAm]^{\frac{1}{2}}} \quad (6)$$

where k_{T} is the subjective threshold (signal-to-noise ratio) criterion.

The results of a TCDD test can be presented either as a contrast-detail diagram or as a threshold detection-index diagram. Hay et al (1985) have defined the detection index as the reciprocal product of threshold contrast and detail diameter:

$$H_{\mathrm{T}}(A) = \left(\Delta S_{\mathrm{T}}(A)\cdot\left(\frac{4A}{\pi}\right)^{\frac{1}{2}}\right)^{-1} \quad (7)$$

i.e.

$$H_{\mathrm{T}}(A) \approx \frac{\left(X_{\mathrm{f}}^{\max}\eta R\frac{\pi}{4}m\right)^{\frac{1}{2}}}{\sqrt{2}\,k_{\mathrm{T}}} \quad (8)$$

Substituting typical values in Equation 8 (viz. $X_{\mathrm{f}}^{\max}$ $m = 0.25$ μC kg^{-1}, $\eta = 0.45$, $R = 10^6$ quanta mm^{-2}/μC kg^{-1} and $k_{\mathrm{T}} = 2$; from Hay et al, 1976) enables a theoretical value of detection index to be predicted. This indicates that under X-ray quantum limited DSF imaging conditions $H_{\mathrm{T}}(A) = 100$ mm^{-1}; this value can be compared with the experimental results presented in the following paper.

The analytical advantage of this concept is that, in theory, for an ideal imaging system $H_{\mathrm{T}}(A)$ assumes a constant value set only by the signal-to-noise ratio at the input to the imaging system and the visual threshold criterion. In practice, inherent technical deficiencies within the imaging system and limitations in the display process degrade the signal-to-noise ratio, thereby reducing the detectability of the low-contrast details and reducing the value of the detection index below that which can be predicted from Equation 8. As a rule, the lower the value of detection index the poorer the quality of the images produced. In addition, detection-index curves diverge from a constant level for both large- and small-diameter details. The former effect is believed to be due to image processing by the mechanisms of the observer's visual system (Chesters, 1982). The latter is known to be due to the unsharpness of the imaging system and/or the observer's visual system.

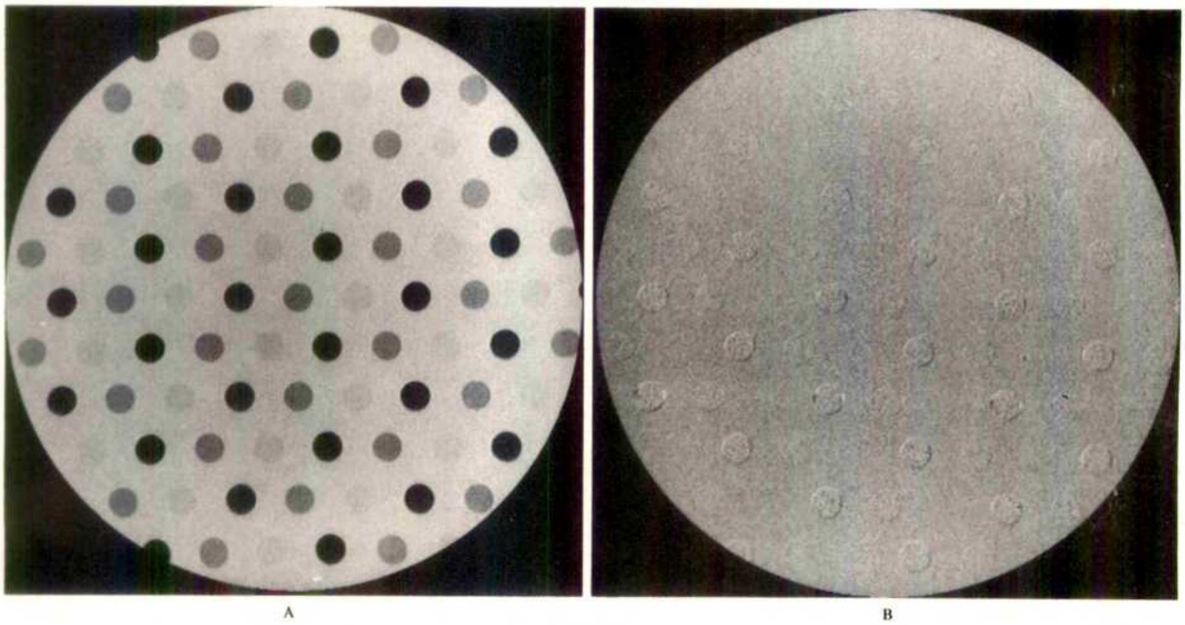


FIG. 7.

(A) Mask image of the test object used to assess systematic misregistration. (B) DSF image of the test object displaying systematic misregistration artefacts.

SPATIAL CHARACTERISTICS OF DSF IMAGES

The spatial characteristics of a DSF system are defined by the unsharpness of the basic imaging equipment, the sampling interval of the matrix array used, the unsharpness of the X-ray focus, and the effect of any conditioning filter which is applied to ameliorate the visual impact of the pixel structure. The relative contributions of these components of unsharpness depend upon the degree of geometrical magnification used; a significant degree of geometrical magnification is not infrequently used in angiographic procedures. It has been reported (Kruger et al, 1981) that under the (high) X-ray tube loading conditions encountered in DSF, the focal-spot unsharpness may increase by as much as a factor of two and therefore make an important contribution to the unsharpness of the images. For the purposes of routine quality control it is possible to check unsharpness using a test grating of suitable resolution, such as the Hüttner No. 18. However, great care must be taken in interpreting results obtained. Users of DSA systems which incorporate digital videodensitometry facilities may prefer to use the slit test object technique described by Cowen et al (1985). Results of this test are less susceptible to the effect of aliasing artefacts.

ASSESSMENT OF SYSTEMATIC MISREGISTRATION

Voluntary or involuntary movement of the patient during the image-acquisition sequence results in the generation of spurious signals known as misregistration artefacts. As these artefacts often have a linear form they represent a powerful source of noise to the diagnostician, who is often looking for opacified vasculature of similar form. Certain DSF systems incorporate computerised pixel-shifting of one of the images to be subtracted in order to reduce misregistration artefacts. This technique has proved only partially successful because of the difficulty of simulating the complex three-dimensional pattern of movement exhibited by the patient. Arguably a more successful

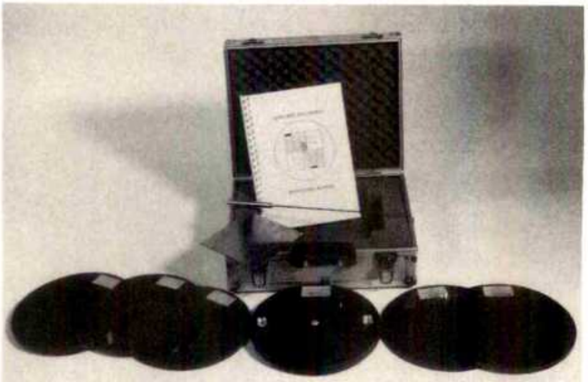


FIG. 8.

Leeds DSF test object set.

technique used to minimise movement artefacts is to remask to an alternative frame in the imaging sequence (Rouse et al, 1984).

It is less frequently appreciated that the DSF system itself can generate spatial misregistration. If the amplitude of this type of misregistration is sufficiently great it is possible that it could be mistaken for anatomical movement. Intrinsic misregistration may arise from instabilities in the television camera scan control, the persistence (lag) of the camera tube, beam deflection effects at the camera target and problems of unequal data transfer paths between the central processor, video-frame store and digital disk.

We have developed a test object to assess the degree and reproducibility of contrast-dependent systematic misregistration artefacts. This device comprises a regular array of disc-shaped details of low, medium and high subject contrast. The test object is left in the image field during the full acquisition phase. An ideal DSF system would eliminate the total image content. Intrinsic misregistration results in an incomplete subtraction of the test details and manifests itself as artefacts, particularly around their rims. It should be noted that one would expect the high-contrast details to be distinguishable from the background by the presence of the noise print (Balter et al, 1984) but not by the presence of artefacts around their perimeters. A mask image of Leeds test object TO.D3 is presented in Fig. 7A. This test object is known colloquially as the "Dalmatian", for obvious reasons. Fig. 7B shows a typical image following subtraction.

SUMMARY

The design of a set of test objects for quality control DSF systems has been described. The resulting test object set is depicted in Fig. 8 and the performance features tested are summarised in Table I.

REFERENCES

AAPM, 1985. *Performance Evaluation and Quality Assurance in Digital Subtraction Angiography*. American Association of Physics in Medicine Report No. 15. (American Institute of Physics, New York.)

Arnold, B. A. & Scheibe, P. O., 1984. Noise analysis of a digital radiography systems. *American Journal of Roentgenology, 142*, 609–613.

Balter, S., Ergun, D., Tscholl, E., Buchmann, F. & Verhoeven, L., 1984. Digital subtraction angiography: fundamental noise characteristics. *Radiology, 152*, 195–198.

Chesters, M. S., 1982. Perception and evaluation of images. *Scientific Basis of Medical Imaging*, Chapt. 7. Ed. by P. N. T. Wells. (Churchill Livingstone, Edinburgh), pp. 237–280.

Cowen, A. R., Haywood, J. M., Clarke, O. F. & Rouse, S., 1985. *A Procedure For Evaluating the Physical Imaging Performance of a Digital Subtraction Fluorography System*. DHSS FAXIL Assessment Report on X-ray Image Forming Systems, No. STB6E/85/4.

DHSS, 1982. *The Testing of X-ray Image Intensifier Television Systems*. UK Dept of Health and Social Security Working Party, Report No. STB/7/82.

FAXIL, 1985. *An Evaluation of the DSA Test Phantoms Which are Commercially Available in the National Health Service*. DHSS Assessment Report on X-ray Image Forming Systems, No. STB6E/85/1.

——1986. *The Application of Digital Subtraction Angiography Equipment in the National Health Service: the Results of a Questionnaire*. DHSS Assessment Report on X-ray Image Forming Systems, No. STB6E/86/26.

Hay, G. A. & Chesters, M. S., 1976. Threshold mechanisms in the presence of visible noise. In *Medical Images. Their Formation, Perception and Measurement*. Proceedings of the 7th L. H. Gray Conference. Ed. by G. A. Hay (Wiley, London), pp. 208–219.

Hay, G. A., Clarke, O. F., Coleman, N. J. & Cowen, A. R., 1985. A set of X-ray test objects for quality control in television fluoroscopy. *British Journal of Radiology, 58*, 335–344.

HPA, 1983. X-ray image intensifier fluorography systems. *Measurements of the Performance Characteristics of Diagnostic X-ray Systems Used in Medicine*—Part VI. UK Hospital Physicists' Association Diagnostic Topic Group, Report No. 32. (HPA, London.)

Kruger, R. A., Mistretta, C. A. & Riederer, S. J., 1981. Physical and technical considerations of computerized fluoroscopy difference imaging. *IEEE Transactions on Nuclear Science, 28*, 205–212.

Riederer, S. J., Belanger, B. F., Keyes, G. S. & Pelc, N., 1981. Iodine sensitivity of digital imaging systems. *Proceedings of the Society of Photo-optical Instrumentation Engineers, 314*, 132–139.

Rouse, S., Haywood, J. M., Cowen, A. R. & Clarke, O. F., 1984. Digital subtraction fluorography: operational and technical aspects. *Radiography, 50*, 51–63.

Verhoeven, L. A. J., 1985. DSA imaging: some physical and technical aspects. *Medica Mundi, 30*, 46–55.

Winkels, T. G. W., 1986. The Philips DVI system: some specific features. In *Digital Subtraction Angiography in Clinical Practice*. Ed. by J. M. Ludwig (Philips Medical Systems, Best, The Netherlands).

Book reviews

Brain Tumours. Their biology and pathology, 3rd edit. By K. J. Zülch, pp. xviii + 704, 1986 (Springer Verlag, Berlin), DM 248.
ISBN 0-387-10933-1 (New York)
3-540-10933-1 (Berlin)

This is the third American edition of Zülch's personal treatise on brain tumours, first published in 1951, and the distillation of a lifetime devoted to tumour diagnosis and research. More than one third of the book is given over to general considerations. The historical development of classification systems leading to the World Health Organisation classification, with which Professor Zülch was particularly associated, is followed by the pathogenesis, natural history, epidemiology and general pathology of tumours. There are also chapters on the mass effects of space-occupying lesions, and on tissue reactions to radiotherapy and chemotherapy, as well as sections on diagnostic approaches and methods. The main part of the book is a systematic description of tumour histopathology, but the term "tumour" is taken broadly, so that parasites and granulomas are also covered: perhaps a surprising decision considering that orbital lesions are given only one page.

Even allowing for the current DM exchange rate, the price at first sight appears reasonable for this weighty book. But as the author concedes, for reasons of economy the number of illustrations has been kept to a minimum. They are excellent pictures and beautifully reproduced but, from the standpoint of illustrating histopathology, insufficient. Indeed, the author suggests that for daily use his two atlases of gross and histological pathology should be employed in parallel with this volume and many references to their illustrations abound throughout the text. Such a triptych, in my opinion, becomes unwieldy and unduly expensive in comparison with several other excellent books currently available. Indeed, although a few years older they are hardly less up to date, for sadly, here is a 1986 publication which does not have a late 20th century attitude. Far too much attention is paid to historical detail and argument and far too many of the references are more than three decades old, in a rapidly changing and expanding field.

One particular strength of the book is its statistical tabulations of incidence for individual tumours by age and sex. This is based on the large personal series that has been studied in Zülch's own department over the years. From these data also derive the extensive illustrative diagrams of the preferential sites of various central nervous system tumours. This feature of the book and the general discussion of tumour growth, mass displacement and effects of therapy will, I suspect, be of more interest to radiologists and clinicians than the histological and nosological minutiae which form the largest part of the text. From a histologist's point of view, however, the purely descriptive chapters are far from ideal. Firstly there is too much citation in place of description, and citation too often of German literature, therefore inaccessible to most international readership. Secondly there is too much repetition: histiocytosis X in both granuloma and lymphoma sections; desmoplastic medulloblastoma appearing again as circumscribed arachnoidal sarcoma; giant-cell glioblastoma described again under monstrocellular sarcoma. These duplications reflect Zülch's somewhat unorthodox views. Another is his belief that pineal germinomas can be split into two separate entities: his arguments are rehearsed in at least three places.

But far more worrying is the sparsity of electron-microscopical and immunological data. Token descriptions of ultrastructure are given, but again citation is too much in evidence. One could perhaps argue that electron microscopy does not play a major role in everyday diagnosis, whereas immunocytochemistry is fast becoming mandatory even in the smaller laboratories, as a regular diagnostic aid. That it is hardly mentioned at all is perhaps the most glaring omission in a volume which, although produced to the high typographical standard we have come to expect from Springer, is unlikely to become a widely used diagnostic manual.

BRIAN HARDING

Imaging of the Temporal Bone: a text/atlas. By Joel D. Swartz, pp. viii + 223, 1986 (Thieme Medical Publishers Inc., New York), DM 168.
ISBN 0-86577-235-5 (New York)
3-13-688401-9 (Stuttgart)

High-resolution computed tomography (CT) is now the imaging investigation of choice for the study of the petrous temporal bone and this book has a consistently high standard of CT pictures: probably the best in any of the several recent works on radiology of the temporal bone. Only two pictures are upside down which is a low error rate given the high potential for such mistakes associated with modern printing methods. A large and comprehensive range of pathology is shown but the title is something of a misnomer as the work consists almost entirely of CT scans with a few angiograms and a small section on magnetic resonance at the end. A solitary plain Stenver's view and no conventional tomograms underline the prompt rejection by the Americans of traditional methods, despite their worth. All imaging is carried out in the three basic planes and the author rightly sees no indication for the plethora of other projections that have been described. Coronal sections are obtained with the chin elevated and sagittal views by reformatting from about 20 axial sections, although a better and easier demonstration of bone detail in the sagittal plane can be obtained by polytomography. Multiple axial CT sections passing through the orbit give a considerable radiation dose to the eye, significantly more than from properly performed polytomography, but this aspect is dismissed in one small, inadequate paragraph.

The book also claims to be a text and it is because of the very high radiological standard that criticism must be directed at some of the claims. To say that radiological findings must influence management seems like stating the obvious but this book overemphasises the value and capabilities of CT. Too often structures, both normal and abnormal, described in the legends cannot be identified in the picture and probably are beyond the limits of resolution of the scanner used. A "large cochlear aqueduct" has not been shown in Figure 6.21, only the external aperture, and several of the pictures purporting to show fenestral otosclerosis need an "eye of faith". Pictures of grommets and eardrum perforations would not seem very relevant to patient management. Many of the line drawings are confusingly at variance with the plane of the radiograph they are supposedly meant to elucidate.

None of these criticisms can detract from the excellence of this work. If carefully studied and critically assessed this expensive book (nearly £60.00) will be a very valuable and indeed essential reference for specialist otology and otoradiology departments. It is not, however, recommended for general radiologists or those in the basic training grades.

P. D. PHELPS

1987, *The British Journal of Radiology*, *60*, 1011–1018

A set of X-ray test objects for image quality control in digital subtraction fluorography. II: application and interpretation of results

By A. R. Cowen, B.Sc., A. Workman, M.Sc., J. M. Haywood, T.Eng.(C.E.I.) and O. F. Clarke, T.Eng.(C.E.I.)

The University of Leeds, Department of Medical Physics, The General Infirmary, Leeds LS1 3EX

(Received November 1986 and in revised form February 1987)

ABSTRACT

In the previous article we introduced a set of test objects for quality control of digital subtraction fluorography (DSF) systems. These test objects have been evaluated using several commercial DSF systems in their clinical environment. In this second article we present test images and results obtained during these trials and explain how the test objects can be used to analyse the imaging performance of DSF systems.

In the preceding article we discussed the general aspects of digital subtraction fluorography (DSF) image evaluation and introduced some of the design concepts used in the development of the Leeds DSF test objects. In this article we describe their application in the field on a variety of different types of commercial DSF systems.

In order to evaluate a DSF system fully, it is also necessary to have available a set of conventional Leeds test objects, a calibrated non-invasive X-ray tube voltmeter, a television oscilloscope and an exposuremeter.

The tests are carried out with the test objects placed on the angiographic table and the 1.5 mm-thick copper filter placed in the beam close to the X-ray tube head. A small gap (typically 10–20 cm) should be left between the image intensifier and table to provide access to the test object for the purpose of accurately positioning it within, and conveniently removing it from, the image field. The source–image receptor distance should be set to a maximum and, if practicable, the antiscatter grid should be temporarily removed.

SYSTEMS VIEWED

The Leeds DSF test objects have been tested upon a variety of types of digital subtraction angiography (DSA) equipment at various diagnostic radiology centres throughout the United Kingdom. Systems examined include:

(1) CGR DG 300
(2) Elscint LS-700
(3) Fischer/Diasonic DA-100
(4) IGE DF-3000
(5) IGE DF-5000
(6) Philips DVI-V
(7) Philips DVI-CV
(8) Picker Adac DAS-211
(9) Quantel Idis
(10) Siemens Angiotron CM
(11) Siemens Digitron 2
(12) Technicare DR 960

The test objects worked successfully with all but two of these types of DSF system. Difficulties were encountered in testing Systems 10 and 11, for two reasons:

(i) the "Digimatic" exposure control system was so constrained it was not possible to set the necessary calibrated X-ray beam conditions,
(ii) these systems operate via average-signal sensing rather than peak sensing of the video.

The test objects can be used with these systems for routine quality-control testing. However, great care must be taken in interpreting the results obtained. It is important to note that these comments are *not* in any way meant as criticisms of the technical or clinical performance of these particular DSF devices. A set of test objects designed for use with digital systems which operate using average-signal sensing of the video are under development.

IMAGE ACQUISITION

Before testing a DSF system it is essential to gain familiarity with the range of image acquisition modes available and identify those which are used clinically. The calibration of the X-ray generator must be checked over the range of exposure factors used clinically. Preferably this should be carried out using a device which displays X-ray tube voltage waveforms. If possible, a sequence of images should also be examined to ensure exposure stability during a DSF run. The image quality of the basic television fluoroscopy system should be assessed (Hay et al, 1985) and if the equipment incorporates a small-format fluorographic camera this should be used to inspect the X-ray image intensifier (Hospital Physicists' Association (HPA), 1983). If satisfactory results are obtained it is then appropriate to evaluate the DSF system in detail.

The Leeds DSF test objects should be used under calibrated X-ray beam conditions of 75 kV with 1.5 mm copper filtration and the appropriate input exposure levels. For devices which operate under full software control it is usually possible to reprogram the X-ray generator parameters and the iris diaphragm setting temporarily for the purposes of quality control. In systems which operate under manual exposure control the radiographic factors are usually set by taking a series of trial-and-error exposures. This process is often facilitated by the presentation of graphic cues on the display monitor which indicate the video peak level achieved.

In order to assess a DSF system it is necessary to change the image content produced by the test objects in the interval between the first (mask) exposure and subsequent test image(s). The resulting difference in image content represents the signal stimulus used to test DSF function. In the standard (angiographic) pulsed mode many DSF systems operate at image acquisition rates of up to 3 frames per s. For the purposes of these tests it is necessary to program a suitably slow image-acquisition rate (say 1 frame per 5 s) or to operate in single-exposure mode. This will minimise the risk of the operator irradiating his/her hands while manipulating the test objects. In the fast (cardiac) pulsed mode the system may operate at acquisition rates of 25 frames per s and therefore it is necessary to manipulate the test objects indirectly.

The stability of the total image acquisition process can be checked by acquiring a DSF run of a plain copper filter and examining the sequence of subtracted images in turn using a high display gain setting (say 16 or greater). Any instability will manifest itself as variations in the level of the subtracted image. If digital videodensitometry facilities are available this variability can be quantified.

Digital subtraction fluorography is not a low-dose imaging technique. The quality of the images produced by a DSF system must be interpreted in the context of the level of radiation exposure used. Systems of different manufacture are adjusted to differing input exposure levels. We believe that the measurement of input exposure levels should, if possible, be carried out using the procedure recommended by the equipment manufacturer. In many cases the DSF system is adjusted to a *peak* input exposure level. Other devices are set-up to a *mean* input exposure level. The correct operating exposure level must be verified before the image quality is evaluated. As an illustration of the levels of radiation exposure typically used in clinical DSF imaging we have measured the levels used by one particular system (Table I). For comparison we also list the levels of exposure measured in conventional and cinefluorography.

In the device under consideration, the exposure per image can be increased (to improve contrast sensitivity) by using multiple (one, two, four and eight) frame integrations. In clinical practice the integration of four frames is generally used.

Dynamic Range Assessment using the Jig Test Object (TO.J3)

The jig test object has been designed to test such features as operating headroom, logarithmic and linear subtraction modes and the power of the electronic noise contribution. TO.J3 is carefully positioned and aligned within the X-ray field using the television fluoroscopy image. The mask image condition is set up by aligning red and white marker lines on the periphery of the two plates. A mask exposure is taken and the top-plate is then rotated through 180° to align the white marker on the top-plate with the white marker on the base-plate. The test images are acquired and subtraction images are presented for assessment on the display monitor. As described in the first article, the test object contains a number of features which must be evaluated in turn.

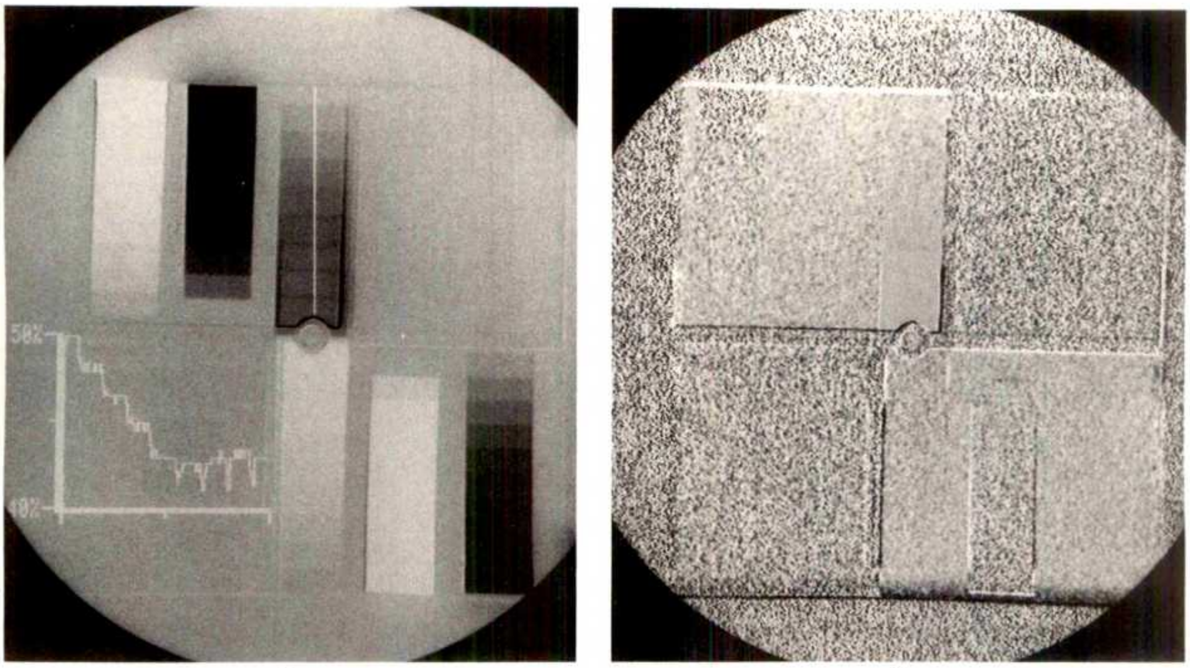
The first factor to examine is the calibration and reproducibility of the operating headroom. Exposure factors should be set up to produce a reference peak video signal level. A video peak level of 80% of the analogue–digital converter range provides the best conditions for using the TO.J3. Under correctly calibrated X-ray beam conditions each step of the highlight step-wedge measures 4% (approximately) of the video range. If an 80% video peak reference level is set up, five of the nine steps available are visualised. The other four steps which exceed the maximum of the analogue–digital converter range are imaged only as a homogeneous rectangular patch in the subtracted image (Fig. 1A). Experience has shown that the region of highlight overload can be more easily discriminated by remasking the subtraction process to another post-rotation image later in the imaging sequence; the saturation region (homogeneous patch) and headroom region (noisy) are quite distinct (Fig. 1B).

Any technical deficiencies which lead to a reduction in the operating headroom result in a reduction in the

TABLE I

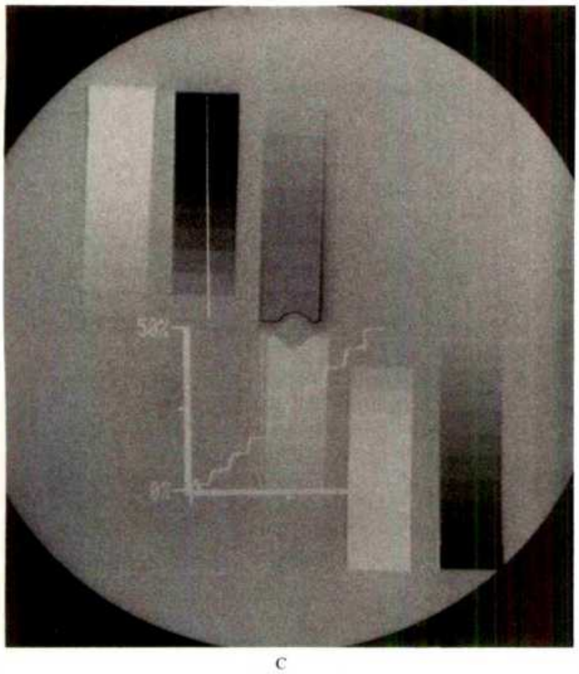
Exposure per image frame (nC kg^{-1})

Image intensifier field selection	DSF (3 frames s^{-1})	105 mm fluorography	DSF (25 frames s^{-1})	35 mm cinefluorography
Normal	66	20	13	4
Mag I	100	29	20	6
Mag II	132	45	26	9



A

B



C

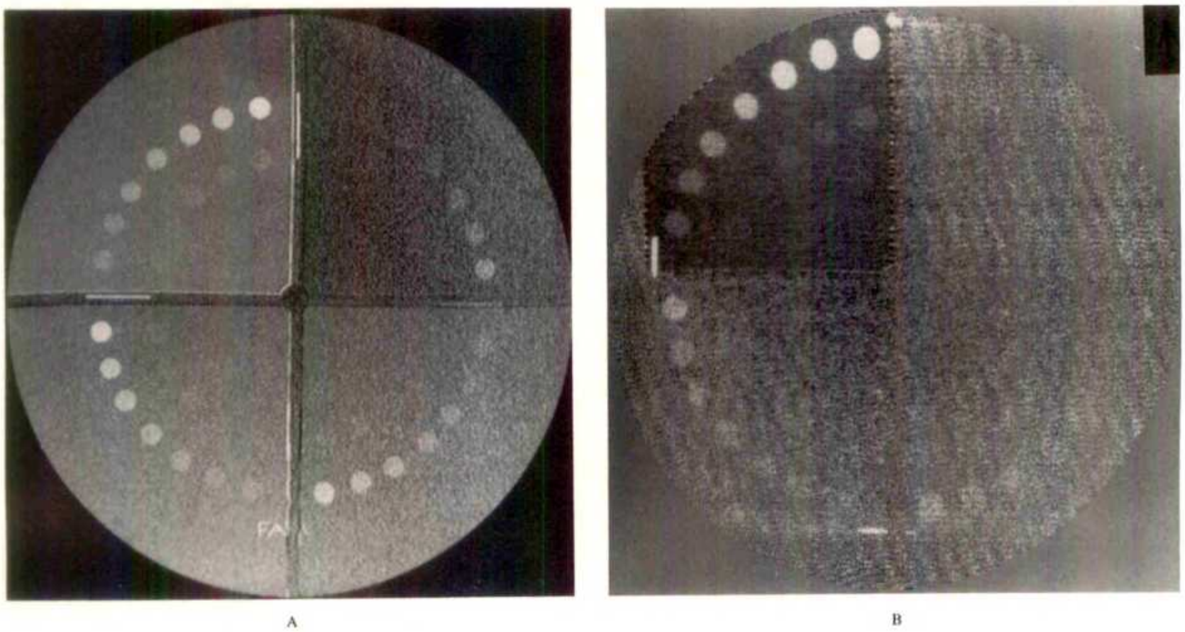
FIG. 1.

(A) DSF image of TO.J3 illustrating the function of the highlight step-wedge. (B) Remasked DSF image of TO.J3 illustrating highlight overload. (C) DSF image of TO.J3; the use of digital videodensitometry to test "log." subtraction.

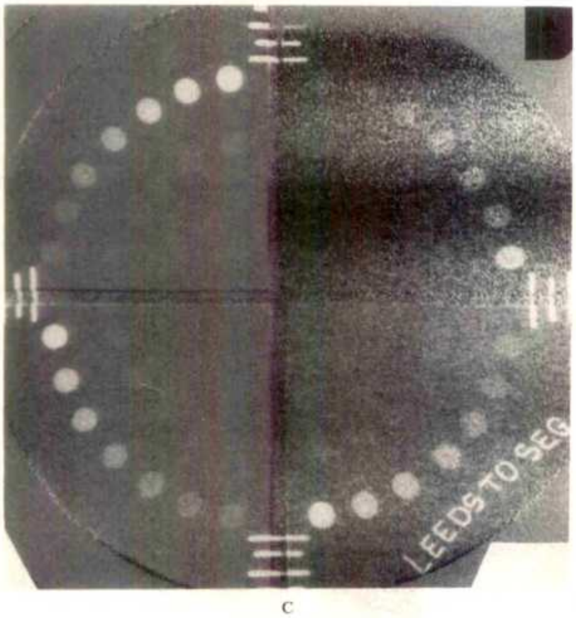
number of steps visualised. Such a decrease in the operating headroom can result from a reduction in the analogue–digital converter range, a change in the television camera overload conditions (*e.g.* due to depletion of the cathode filament or decrease in the camera-tube grid voltage), or any elevation of the video-peak-sensing level. On the other hand, a reduction in the video-peak-sensing level results in an increase in the operating headroom and thereby in the number of steps visualised.

The reproducibility of the logarithmic and linear subtraction modes can be assessed using the appropriate "log." and "lin." high-contrast step-wedges. Interpretation of these step-wedge results is facilitated using digital videodensitometry readout of the data (Fig. 1C). Correct function is represented as approximately linear readout values from the appropriate test wedge. For those systems which do not possess an analytical capacity these features may also be checked using a video waveform presented on an oscilloscope, triggered at television field repetition rates; a full explanation of this method was presented by Cowen et al (1985).

The power of the electronic noise is checked using the low-contrast square detail which is rotated into the (top right) lowlight test sector. The visibility of the resulting low-contrast detail produced following subtraction is limited by the power of the television electronic noise. An increase in the power of this noise reduces the visibility of this detail. Digital subtraction fluorography systems which incorporate region-of-interest measure-



A B



C

Fig. 2.

(a) DSF image of TO.Q3. (b) DSF image of TO.Q3 produced by a system exhibiting excessive electronic noise. (c) DSF image of TO.Q3 produced by system exhibiting low-frequency electrical interference.

ments can be used to make an objective measurement of the electronic noise contribution.

Dynamic Range Evaluation using the Quadrant Test Object (TO.Q3)

The second test for dynamic range uses two test objects, firstly the quadrant filter, which provides the attenuation range, and secondly an array of four sets of low-contrast test details. These two test objects are superimposed and aligned and a mask image acquired. Following the mask exposure the test detail plate is removed from the X-ray beam and is replaced by a uniform Perspex plate of equivalent base thickness.

Within the limits of the dynamic range of the DSF system, digital subtraction eliminates the impression of the quadrant filter, leaving an image of the array of test details superimposed upon a noisy background of constant brightness. In the sector which has the highest X-ray transmission the power of the noise is low and the visibility of the details progressively deteriorates in the sectors of decreasing X-ray transmission. Figure 2a illustrates an image produced by the DSF system operating in the pulsed acquisition mode. The device produces satisfactory subtraction over all four sectors of the test object.

The degradation of the signal-to-noise ratio in regions of the image formed at progressively lower X-ray intensities is reflected in the reduction in the number of details which can be perceived. A significant increase in electronic noise produces a selective reduction in the visibility of details situated in regions at low X-ray intensities within the image. It is interesting to note that the power of the noise in regions of the DSF image which are limited by television camera noise is independent of the level of X-ray transmission. Provided an image detail has sufficiently high subject contrast, the DSF system can reproduce it over a remarkably wide range of exposure levels.

In practice a variety of processes can degrade the DSF dynamic range. For example, Fig. 2B illustrates a system exhibiting excessive electronic noise. In Fig. 2C we see a system which exhibits a low-amplitude, low-frequency electrical interference; it should be noted that this additive interference has greatest amplitude in the test-object sector of lowest X-ray transmission.

ASSESSMENT OF LOW-CONTRAST SENSITIVITY USING TO.20$\bar{V}$

Test images of TO.20$\bar{V}$ should be obtained over the range of input exposure conditions typically used in clinical DSF. Following digital subtraction the static structure noise is effectively eliminated, producing enhanced low-contrast sensitivity (Cowen et al, 1984). Several subtracted images should be acquired in order to provide several statistically independent samples. Images should also be obtained after the test object has been shifted slightly, to reduce the influence of the matrix structure on the visibility of small-diameter, high-contrast details. Images would normally be read from samples recorded on hard-copy film. Care should be taken to optimise viewing conditions. Alternatively, images can be viewed directly from the video display unit. Films should be read by two (or more) experienced observers and the results pooled. Observers should be permitted to adjust their viewing distance and to use a magnifying lens in order to optimise their large- and small-detail contrast detectability. In order to maintain external noise-limited imaging conditions (*i.e.* minimise the contribution of internal visual noise) the contrast amplification of the display process should be optimised.

Figure 3A presents threshold detection-index curves derived from images produced by the reference DSF system. Images were recorded at four different levels of input exposure using one, two, four and eight television frame integrations. For comparison we also include equivalent results obtained in small-format fluorography. The large- and medium-diameter low-contrast sensitivity of DSF imaging is approximately three times higher than that of 105 mm fluorography. This improvement cannot be explained solely by the three-fold higher radiation exposure per image used to produce the digital image. Rather, we believe that it also reflects the elimination of system structure noise and the advantages of contrast amplification. The use of eight-frame integration further improves imaging performance (by approximately a factor of two) over single-frame DSF. This degree of improvement is less than would be predicted by X-ray quantum statistics (*i.e.* $\sqrt{8}$) and possibly reflects the finite grey-scale discrimination of the digitisation process and/or the presence of remanent structure noise arising from temporal instabilities of the television raster (Arnold et al, 1984).

The comparatively poor spatial resolution of DSF imaging produces a more rapid reduction in the value of detection index for progressively smaller-diameter

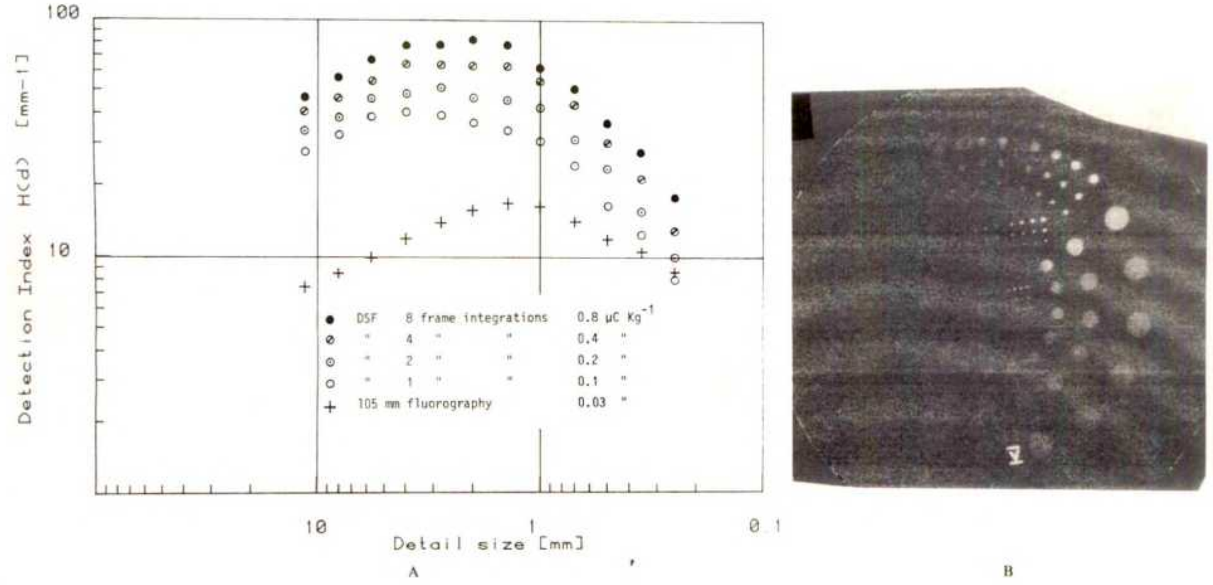


FIG. 3.

(A) Threshold detection-index curves. (B) DSF image of TO.20$\bar{V}$ produced by a system exhibiting poor TCDD performance.

details than is found in 105 mm fluorography. Nevertheless, over the range of detail diameters examined, the detection index of DSF remains superior to that of 105 mm fluorography. These findings indicate that at threshold levels of visibility, the excellent low-contrast sensitivity of digital fluorography can compensate for the greater sharpness, but lower-contrast sensitivity, of film-based fluorography.

The level of contrast sensitivity (hence threshold detection index) exhibited by a system is sensitive to the level of extraneous noise and/or the presence of excessive internal contrast loss. A test image from a system we have examined which exhibited poor threshold-contrast detail-detectability (TCDD) performance is presented in Fig. 3B.

MONITORING THE UNSHARPNESS OF DSA SYSTEMS

For the purposes of quality control, the spatial-imaging characteristics of the DSF process can be monitored using a Hüttner Type 18 resolution test grating. It is essential to remove the antiscatter grid before carrying out this test. Standard X-ray beam conditions of 75 kVp plus 1.5 mm copper are used to limit the subject contrast in the test image. The resolution test grating was imaged using two geometrical arrangements which we believe define the extremes of the range which may realistically be used in clinical examination. Contact imaging (no magnification) was used to measure the unsharpness of the DSF system alone. The test grating was positioned at the centre of the image field and orientated at 90° to the television raster structure. Four television frames were integrated in order to improve the accuracy of the measurement. Measurement (viewing) conditions were optimised by careful adjustment of the display contrast and brightness controls. The spatial resolution of the reference DSF system has been compared with that of the X-ray image intensifier (measured using 105 mm fluorography) and television fluoroscopy: the results are presented in Table II. The measured spatial-resolution limit of the reference DSF system and the value of the resolution limit estimated from the known spatial sampling interval of the matrix array and the effective field diameter of the X-ray tube are also presented.

Two-fold geometrical magnification (obtained by positioning the test grating equidistant from the X-ray focus and the X-ray image intensifier input window) was used to examine the contribution of the focal-spot unsharpness. To ensure that any "blooming" of the X-ray focus which would normally occur is included in the assessment it is essential that the spatial-resolution limit be measured under clinically realistic X-ray tube loading conditions. The value of spatial resolution determined is scaled back to the input plane of the image intensifier in order to compare it with the value measured in contact imaging. The measurements were carried out with the 17 cm-diameter field selected in order to maximise sensitivity to the focal-spot unsharpness. The spatial-resolution limits were:

for contact imaging → 1.15 cycles mm^{-1} and,
for two-fold geometrical magnification → 0.95 cycles mm^{-1}.

The geometrical magnification reduced the resolution limit by a factor of approximately 0.2. Such a reduction is consistent with the effect of a focal spot of the quoted size. These results indicate a clear but not dramatic reduction in total system sharpness due to "blooming" of the X-ray focus. Digital subtraction fluorography based on a finer matrix array (*e.g.* 1024 × 1024) will increase the relative importance of the focal-spot unsharpness.

It should be noted that measurement of spatial-resolution limits in digital X-ray images is not a trivial procedure. Although it can be used quite successfully for the purposes of routine quality control we would not recommend its use for system performance evaluation, as the results are prone to errors due to aliasing effects. The reference DSF system employs Nyquist filters at both the input and output to minimise this effect (Verhoeven, 1986). Systems of other design may not include low-pass filtration to minimise aliasing. In such systems the true spatial resolution is difficult, if not impossible, to estimate accurately from a test grating.

ASSESSMENT OF SYSTEMATIC MISREGISTRATION (TO.D3)

In the preceding article we described a test object designed to assess systematic misregistration. For perfect subtraction the test details are eliminated, leaving only their noise print (Balter et al, 1984). In practice we find that in most systems only the low-contrast details are effectively subtracted: the higher-contrast details are often imperfectly subtracted, leaving artefacts around the rim of the detail. The degree and orientation of these artefacts vary with position in the image field and from image to image. The variation in the distribution of misregistration artefacts during a

TABLE II

A COMPARISON OF SPATIAL RESOLUTION LIMITS (CYCLES MM^{-1})

Image intensifier field selection	105 mm fluorography	TV fluoroscopy	DSF (measured)	DSF (estimated)
Normal	3.3	1.1	0.55	0.64
Mag I	4.0	1.6	0.78	0.88
Mag II	5.2	2.2	1.15	1.28

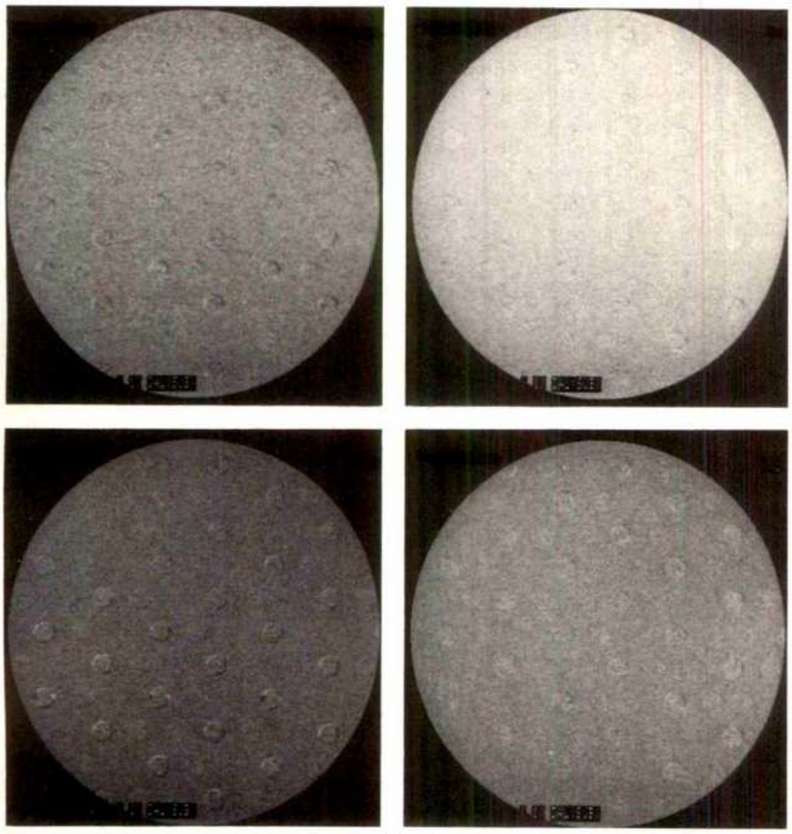


FIG. 4.

DSF imaging sequence of TO.D3 illustrating changes in systematic misregistration from image frame to frame.

typical DSF imaging sequence is presented in the four frames of Fig. 4. The strength of the misregistration artefact usually increases as the number of frames separating the two images to be subtracted is increased. This effect may be related to the deflection of the scanning electron beam in the camera tube at regions of the target where large differences in accumulated charge exist. We have also found that the degree of misregistration is always most pronounced when the subtractions are referred to the initial mask frame; remasking to an image frame acquired later in the series reduces the power of the misregistration artefacts (Cowen et al, 1985).

The degree, type, and nature of the misregistration artefacts vary with equipment design. One design of system appears to have largely solved this problem. Other designs exhibit severe intrinsic misregistration which is likely to prove clinically significant. Systematic misregistration will also depend upon hospital environmental service factors such as the quality of the electrical supply to the room in which the system is operating. Careful inspection of clinical images at the General Infirmary produced limited evidence of systematic misregistration affecting diagnostic performance. This is not to say, however, that such artefacts could not prove a clinical problem for systems of inferior specification and/or those which are operating under unsatisfactory conditions. Furthermore, this effect could also grow as equipment degrades with age or drifts out of adjustment. The spurious nature of systematic misregistration artefacts means that it may not be possible, as it often is for patient movement artefacts, to eliminate them by computerised pixel shifting.

CONCLUSIONS

Over the last 3 years we have developed a set of test objects to evaluate the performance of DSF systems. The design and calibration of these test objects are compatible with that of the conventional Leeds X-ray test objects used in television fluoroscopy and small-format fluorography. The Leeds DSF test objects were originally designed for the purpose of monitoring and maintaining the clinical imaging service provided by the DSF equipment in the General Infirmary (Cowen et al, 1985). We have subsequently found that the current set of Leeds DSF test objects (*i.e.* those described here) are fully compatible with a wide range of commercial DSF systems. Our experience both in house and in the field leads us to believe that the implementation of a rigorous quality-control regime is essential to ensure the optimum clinical DSF service. Obviously there is no substitute for a thorough understanding of DSF imaging science and a detailed knowledge of the technical and operational features of the DSF equipment. We have found that the application of these test objects not only provides a sound framework within which to carry out quality-control tests but also provides a means to gain a deeper understanding of the technical characteristics of individual devices and of the fundamental mechanisms of DSF imaging in general.

Acknowledgments

We wish to express our gratitude to Mr C. W. Hancock, Project Officer (FAXIL) of the Scientific and Technical Branch of the United Kingdom Department of Health and Social Security for his support and encouragement during the development of these test objects. Mr A. Workman is supported by the DHSS FAXIL Research Grant. The test objects were manufactured by Mr S. McArdle of this department.

REFERENCES

Arnold, B. A. & Scheibe, P. O., 1984. Noise analysis of a digital radiography system. *American Journal of Roentgenology, 142*, 609–612.

Balter, S., Ergun, D., Tscholl, E., Buchmann, F. & Verhoeven, L., 1984. Digital subtraction angiography: fundamental noise characteristics. *Radiology, 52*, 195–198.

Cowen, A. R., Haywood, J. M., Rouse, S. & Clarke, O. F., 1984. Digital grey-scale fluorography: a new approach to digital radiographic imaging. *British Journal of Radiology, 57*, 544–538.

Cowen, A. R., Haywood, J. M., Clarke, O. F. & Rouse, S., 1985. *A Procedure For Evaluating the Physical Imaging Performance of a Digital Subtraction Fluorography System.* DHSS FAXIL Assessment Report on X-ray Image Forming Systems, No. STB6E/85/4.

Hay, G. A., Clarke, O. F., Coleman, N. J. & Cowen, A. R., 1985. A set of X-ray test objects for quality control in television fluoroscopy. *British Journal of Radiology, 58*, 335–344

HPA, 1983. Part VI. X-ray image intensifier fluorography systems. *Measurement of the Performance Characteristics of Diagnostic X-ray Systems Used in Medicine*, UK Hospital Physicists' Association Diagnostic Radiology Topic Group Report No. 32.

Verhoeven, L. A. J., 1985. DSA imaging: some physical and technical aspects. *Medica Mundi, 30*, 46–55.

1987, *The British Journal of Radiology*, *60*, 1019–1021 OCTOBER 1987

Technical notes

Use of a simple Leeds test object for rapid assessment of image intensifiers

By A. M. Grant, B.Sc., T. M. Kehoe, B.Sc., M.Sc. and J. Law, B.Sc., Ph.D.

Department of Medical Physics and Medical Engineering, Edinburgh University and Western General Hospital, Edinburgh

(*Received September 1986 and in revised form May 1987*)

It is clearly desirable to perform routine checks on the image quality provided by image intensifier-TV systems as used in diagnostic radiology. Such checks require appreciable time from experienced staff. The tests are commonly carried out by medical physics departments, sometimes on a regional basis. Many departments, however, do not have sufficient resources to make complete checks at a reasonable frequency on all intensifier systems in their region, or even in a single district.

The Department of Medical Physics at Leeds General Infirmary has produced a simplified test object (type TOR TVF) at modest cost, together with a set of instructions which enable the user to make quick visual checks of image distortion, contrast and resolution, without any other equipment, and all within less than half an hour per intensifier system. The results of these checks are an index of contrast, a maximum resolvable line frequency under stated conditions, and a qualitative assessment of distortion. With a little training these checks can be performed by a technician with no prior experience.

The primary application of this test object is to identify any deterioration in performance of an intensifier system over a period of months or years. However, in considering which equipment to recommend for replacement each financial year, it is also advantageous to compare systems at a given time. Although a single test object used in a simplified way can give only an imperfect indication of how any system compares with others, it may nevertheless be valuable, supplementing rather than supplanting the subjective reports of radiologists in arriving at a decision to replace equipment. Although most radiologists routinely use more than one intensifier system each week, few regularly use more than two, yet there may be many in an area or district.

Until experience had been gained, there was little way of telling whether a particular result indicated good, average or poor performance of a system in relation to other systems. With experience it became possible to quantify these three categories, at least for contrast and resolution. Further experience demonstrated the reliability of these assessments and allowed estimation of a standard deviation for each. The purpose of this note is to report that experience, now based on measurement of 41 intensifier-TV systems, 25 of which have had a repeat assessment after an interval of several months.

EXPERIMENTAL METHOD

The Leeds test object, type TOR TVF, consists of a circular strip of lead for assessment of television distortion, a series of discs of decreasing thickness to assess low-contrast sensitivity, and a series of line-pair patterns of increasing spatial frequency to assess the limiting resolution. There is a 1 mm copper filter which serves to reduce the dose rate so that the intensifier is working at normal clinical dose levels. This also serves to harden the beam, thereby largely removing effects due to variations in filtration between X-ray tubes. Unless otherwise stated, the test object was used according to the instructions accompanying it, prepared by the Leeds Medical Physics Department.

The test object was placed as close as possible to the entrance plane of the image intensifier and orientated at right angles to the television lines. The antiscatter grid was removed whenever possible. (If the grid could not be removed the test object was orientated so that the lines of the bar patterns were at 45° to the television lines.) The 1 mm copper filter was placed in the beam as close as possible to the X-ray tube and 70 kV (as indicated on the control panel) was selected. If 70 kV was not available, the nearest value was used (the same value being used each time the set was tested). The kV value was recorded. To set the TV monitor controls, the X-ray tube mA was adjusted to give a "reasonable" image, *i.e* the best visibility of the greatest number of details, and the mA value was recorded. The test object includes two squares with contrasted circles inside. The brightness and contrast controls on the monitor were then set so that the black circle could be seen in the dark-grey square at the same time as the white circle could be seen in the light-grey square. The equipment was then ready for assessment.

The test-object instructions were closely followed; however, they do not include any check that the indicated 70 kV is in fact correct, or any requirement to measure or standardise dose rates. These points are referred to later.

ASSESSMENT PROCEDURE

An assessment of distortion was made by judging whether or not the circular lead strip appeared circular.

To assess contrast, the number of visible discs was counted, from the darkest to a maximum of 14. This was done at a viewing distance about four times the diameter of the displayed field. Often a number of discs could be clearly seen and one or two were only just visible. On these occasions two numbers were recorded, but subsequently the mean value was taken as the result.

To assess the limiting resolution, the 1 mm copper filter was removed and the lowest kV available was selected. The mA was adjusted to give as bright an image as possible without saturating the monitor. (With automatic mA control the test-object instructions advise placing some low-atomic-number material, *e.g.* a telephone directory, in the beam where necessary to reduce the exposure rate.) Starting with the coarsest group, the number of spatial-frequency groups that could be resolved was recorded. No viewing distance was specified, so this was done at whatever distance suited the observer.

INITIAL ASSESSMENTS AND REPRODUCIBILITY

The main series of assessments was carried out by one of us (AMG) alone, but at both the beginning and the end of the series another of us made independent assessments and found agreement in scores of both contrast and resolution. On one sample system, other staff were invited to record their assessments, and only one person out of six showed any variation in score of more than one step on either contrast or resolution. This confirmed that image scores were satisfactorily free from observer variation.

Scores were then checked against variation in indicated kV and indicated mA. No change in contrast could be detected from 80 to 65 kV, and only the minimum change of one step was seen at 61 kV. The same was true for resolution. Tube current was varied from below 0.5 mA to more than 3 mA, at kV values from 57 to 70, with no detectable change in resolution score. These variations involved more than a three-fold change in dose rate. Thus the technique appears insensitive to quite large changes in kV, mA and dose rate, which lends support to the instructions in not regarding these as critical.

For the first seven systems assessed, the results were compared with the subjective assessments of the radiologists using them, and a good correlation was found. Later, a different subgroup of eight systems was compared with different radiologists' reports and again excellent agreement was shown.

RESULTS

Forty-one installations were assessed, and 25 were reassessed after an interval of up to 14 months.

Distortion was assessed subjectively, with serious distortion recorded by a quick sketch. Of the 25 sets assessed twice, only four were recorded as showing significant distortion on both occasions, but six showed distortion on one assessment. Of the other 16 systems assessed only once, five were recorded as showing distortion.

From the first assessments of 41 installations, the results for both contrast and resolution were graded good, average or poor. The values of contrast and resolution used to define these groups were arbitrarily chosen so that approximately one quarter of the total were graded good and one quarter poor. In addition to the checks on reproducibility described above, the two sets of results for the 25 installations which had repeat assessments have been compared.

This approach would be affected by any deterioration in actual performance of the X-ray equipment, but the average change in contrast score was only +0.4, and in resolution score it was −0.4. Changes in contrast score gave a standard deviation of 1.5 and changes in resolution score gave 1.7, *i.e.*, in 68% of the repeat assessments the score change was less than these quantities. This seems to be an acceptable level of consistency. Taken with the close agreement of different observers, referred to earlier, it gives reasonable confidence in the validity of assessment, at least on the level of good, average and poor.

The contrast and resolution scores are shown in the histograms in Fig. 1. The corresponding contrast and resolution levels are shown in Table I. The histogram for contrast is approximately a normal distribution centred on Disc 12 (2.7% contrast) but with a pronounced tail on the poor side. For resolution, the histogram appears broader, but there is still a pronounced tail of poor systems. On six out of 66 assessments, a system was graded poor on either contrast or resolution and good on the other. Five

TABLE I

CONTRAST AND RESOLUTION LEVELS FOR GOOD, AVERAGE AND POOR INTENSIFIER SYSTEMS

	Contrast			Resolution		
	Discs seen	Contrast level	No. of systems	Patterns seen	Spatial frequency (1 pair/mm)	No. of systems
Good	≥ 12½	2.5%	10	≥ 9½	1.3	9
Average	9½–12	4–2.7%	21	6½–9	0.95–1.25	19
Poor	≤ 9	4.5%	10	≤ 6	0.90	13

1987, *The British Journal of Radiology*, *60*, 1021–1022 OCTOBER 1987

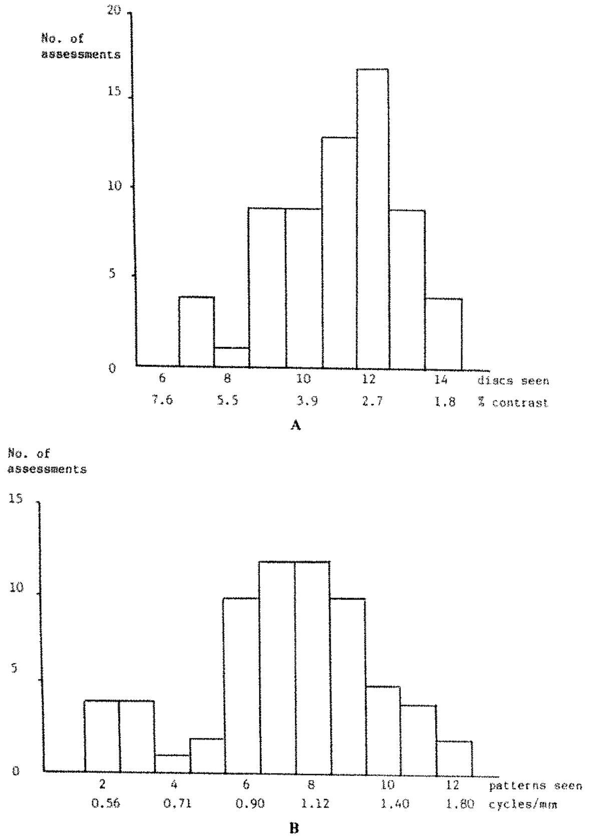


FIG. 1.
(A) Contrast level. (B) Resolution level.

assessments gave a poor result in both respects and 14 were graded poor in one and average in the other. When considering arguments for replacement of equipment, an assessment of poor in both respects would be likely to carry some weight, with slightly better scores having correspondingly reduced significance. Of those systems rated as poor, the majority had CsI-type intensifiers.

In addition to the 41 intensifier systems with TV, four other intensifier systems with mirror viewing were also assessed. For contrast, three of the four were rated poor, the other rated average. For resolution, however, three were rated good and one average, and on the overall assessment they matched the average for the group of 41.

In 16 of the assessments the dose rate incident on the test object was measured. This was then compared with the contrast and resolution results, but no correlation was found in either case. This is perhaps not too surprising: a higher dose rate may be correlated with better image quality, or with equipment in poorer condition having poorer image quality.

CONCLUSION

This note shows what can be done with limited resources of staff, time and equipment, in the belief that even a very limited and simplified assessment of intensifier systems is better than none, provided that the conclusions derived are not the sole determinant of action.

The test object described has proved a useful tool in identifying the poorest performing systems in a region, and can be used to identify ones which are deteriorating appreciably. It requires only a short time on each X-ray set, no other equipment is needed and it can be used by staff with no great experience. Results obtained with it have already been taken into account in considering priorities for equipment replacement, though image quality so assessed is only one factor among many. They will also provide a baseline in the future, and assessments will be repeated annually. The X-ray equipment in the region is believed to be typical, and the criteria identified may be of more than local value.

A simple technique for double-contrast oesophagrams

By P. M. F. Yoong

Department of Diagnostic Radiology, Royal Perth Hospital, Box 2213 GPO, Perth, Western Australia 6001

(Received December 1986)

A simple technique to produce consistently excellent double-contrast views of the oesophagus is described. Double-contrast views of the oesophagus are particularly important in visualising small mucosal lesions and many techniques have been described by several authors. The usual method is with the patient in the erect left posterior oblique (LPO) position rapidly gulping a high-density barium suspension, immediately after ingesting effervescent agents (Laufer, 1979).

METHOD

Fifteen millilitres of an acidic solution (Negative C, Part I Field System) is added to 100 ml of a high-density barium suspension (250% weight/volume Field

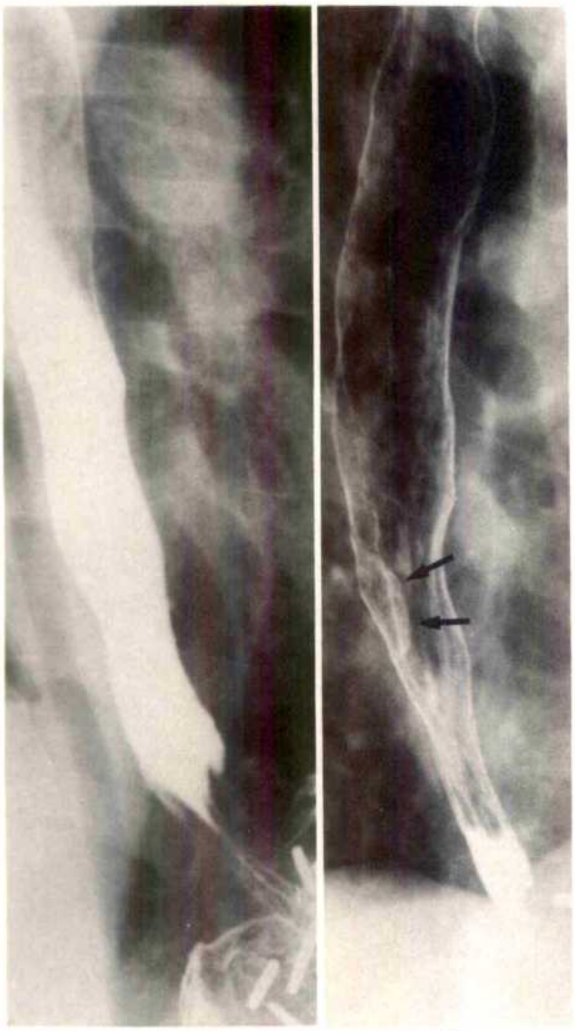


FIG. 1.

(A) Essentially single-contrast view of the lower oesophagus. (B) Double-contrast view showing an early adenocarcinoma.

System), together with three drops of a bubble breaker containing simethecone. The patient is placed in the erect LPO position and asked to drink 15 ml of an alkaline solution (Negative C, Part II Field System). This is followed immediately by ingestion of the barium suspension with the added acidic solution. Spot views of the oesophagus and consistently excellent double-contrast views of the oesophagus are then obtained.

RESULTS AND DISCUSSION

Over 200 examinations of the oesophagus have been performed with excellent double-contrast views and maximal distension of the oesophagus using the method described.

With the method described by Laufer (1979), double-contrast oesophagrams can be obtained in a large proportion of patients and it is particularly successful in patients with a lax lower oesophageal sphincter. However, some patients have difficulty in gulping the high-density barium rapidly and this prevents optimal distension of the oesophagus. We have also found that in some patients, although the upper and mid-oesophagus are visualised in double-contrast, it is often not possible to demonstrate the lower oesophagus in this way. Other groups of patients who prove difficult are those with dysphagia or those who have had previous fundoplication.

CASE REPORT

A 75-year-old man had had a fundoplication 2 years previously for severe reflux oesophagitis. An oesophagram was performed for dysphagia and the initial examination failed to show the lower oesophagus in double-contrast because of the fundoplication (Fig. 1A). Using the method described, a satisfactory double-contrast study was obtained, which showed a polypoidal wide-based lesion, confirmed on biopsy to be an early adenocarcinoma, arising from a Barrett's oesophagus (Fig. 1B).

REFERENCE

LAUFER, I., 1979. *Double Contrast Gastrointestinal Radiology* (W.B. Saunders Co., Philadelphia).

1987, *The British Journal of Radiology*, 60, 1023–1025 OCTOBER 1987

Case reports

Idiopathic spinal arachnoid cyst and syringomyelia

By A. G. Clifton, M.A., M.R.C.P., *L. Ginsberg, Ph.D., M.R.C.P., *W. J. S. Webb, B.Sc., M.R.C.P. and A. R. Valentine, M.B., D.M.R.D., F.R.C.R.

Departments of Radiology and *Neurology, Royal Free Hospital and School of Medicine, London NW3

(*Received January 1987*)

There have been isolated reports in the literature of an association between spinal arachnoid cyst and syringomyelia as a sequel to spinal trauma. We describe a case of syringomyelia of the cervico-thoracic cord associated with an idiopathic, dorsally situated intradural arachnoid cyst of the upper thoracic segments. A causal relationship is suggested.

CASE REPORT

A 53-year-old man presented with 1 week's unsteadiness of gait which had developed abruptly and worsened during the first 3 days of his illness. Over the same period he became aware of lower-limb sensory disturbance, his legs feeling encased in tight metal bands. There were no other neurological symptoms; in particular, no sphincter disturbance or back pain. There was no past medical history or family history of note.

On examination, higher cerebral function and cranial nerves were found to be normal. Fine finger movements of the left hand were impaired, but the upper limbs were otherwise normal. In the lower limbs, there was increased tone bilaterally but no weakness. There was heel/shin ataxia, more marked on the left. Gait was ataxic and spastic, and tendon reflexes were symmetrically brisk with bilateral extensor plantar responses. Superficial abdominal reflexes were absent. Spinothalamic sensation and proprioception were normal, but vibration sense was impaired to the level of the clavicles. Examination of other systems revealed no abnormality.

Routine haematological and biochemical investigations, including thyroid function, serum B12 and serological tests for syphilis, gave normal or negative results. Cerebrospinal-fluid (CSF) pressure and constituents were normal apart from an elevated protein content of 0.62 g/l (normal range = 0.1–0.4 g/l); CSF protein electrophoresis revealed a normal pattern. Visual and auditory evoked responses were unremarkable, but somatosensory evoked potentials to left median nerve stimulation showed an increased interwave latency (N9–N13).

Skull and cervical spine radiography and cranial computed tomography (CT) scan were normal. Chest radiograph showed a mild thoracic scoliosis.

Radiological investigation

Aqueous myelography demonstrated a spinal intradural arachnoid cyst between T6 and T3, lying dorsal to the spinal cord (Fig. 1). Its distended fundus lay at T3 and compressed the cord. Immediately above this level the cord was expanded, returning to normal size and shape at C4 (Fig. 2). There was no cerebellar ectopia. Computed myelography demonstrated the marked cord compression at the level of the distended arachnoid cyst (Fig. 3). The spinal cord was expanded cranially and further CT examination at 24 h revealed dense opacification of a syrinx between T2 and C5 (Fig. 4). The configuration of the latter was further assessed with magnetic resonance imaging (Fig. 5). The patient subsequently underwent laminectomy to enable fenestration and collapse of the arachnoid cyst.

DISCUSSION

Intraspinal arachnoid cysts are relatively common incidental findings at myelography, especially in the thoracic region, but are only rarely of clinical significance (Kendall et al, 1982).

The association of a spinal arachnoid cyst and syringomyelia has been reported following spinal trauma (McLean et al, 1973; Haney et al, 1985). Syringomyelia apparently developing secondary to cord compression due to a distended spinal arachnoid cyst in the absence of trauma has not previously been described.

Syringomyelia following spinal trauma and/or arachnoiditis is well recognised and mechanisms have been proposed to explain the presence of cord cavitation. McLean et al (1973) describe the production of a necrotic, blood-filled intramedullary cavity at the site of spinal-cord trauma, together with fixation of the cord by fracture or arachnoiditis. Complete subarachnoid occlusion is usually demonstrable. With such cord fixation, movement of adjacent vertebrae may produce lengthening of the cord and a pressure rise in the cavity, leading to disruption of adjacent tissues along pathways of least resistance. Valsalva manoeuvres may also lead to cyst extension by intermittently raising intraspinal pressure.

We believe that syringomyelia developed in our patient as a consequence of localised cord compression due to the adjacent distended arachnoid cyst. It is postulated that the chronic, albeit intermittent, cord compression resulted in focal necrosis and progressive cephalad cavitation. In retrospect, the abrupt onset of spastic paraparesis was the most intriguing feature of this case. The clinical presentation was more suggestive of extrinsic cord compression than of an intramedullary lesion. We therefore believe that the patient developed symptoms only when the arachnoid cyst became persistently distended. The previous intermittent expansion and collapse of the cyst with concomitant

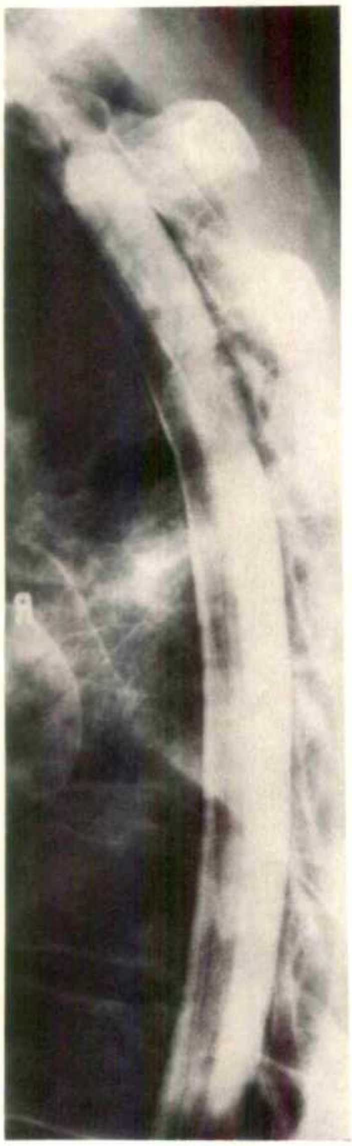
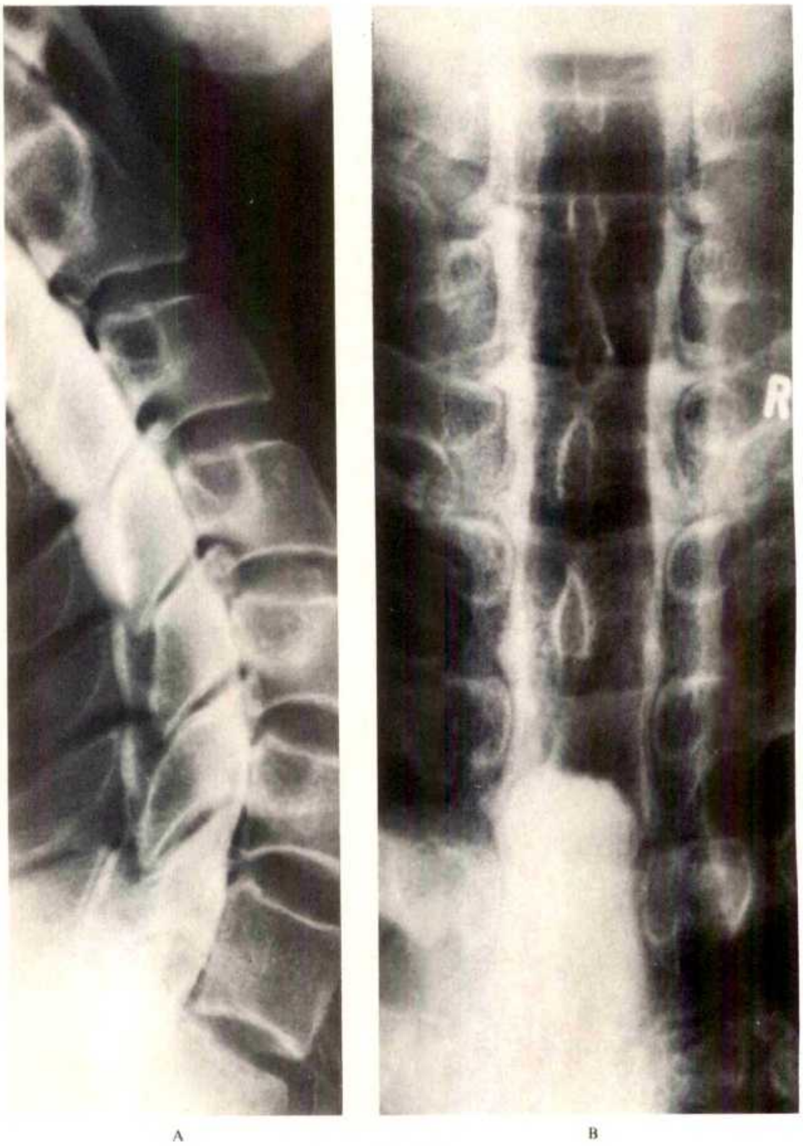


FIG. 1.

Thoracic myelography, lateral projection, shows a distended arachnoid cyst, fundus at T3, compressing the spinal cord from the dorsal aspect.



A

B

FIG. 2.

Myelography shows the expanded lower cervical (A) and upper thoracic (B) cord segments above the arachnoid cyst.

cord cavitation was clinically silent and of indeterminate duration. This hypothesis is supported by the patient's sustained clinical improvement following surgical decompression.

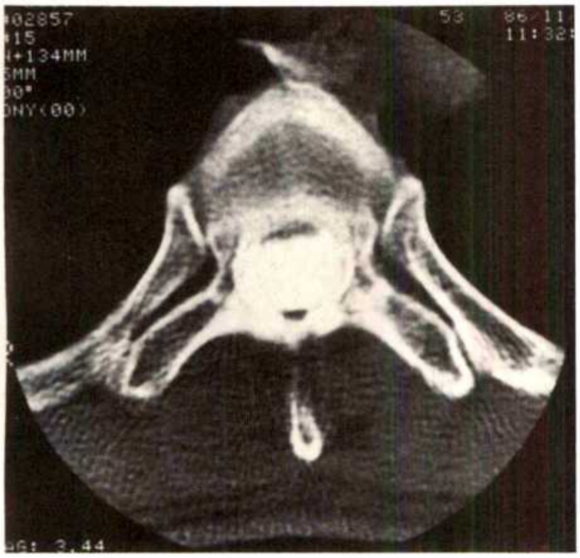


FIG. 3.

Computed myelography (immediate) shows gross cord flattening by the fundus of the cyst.

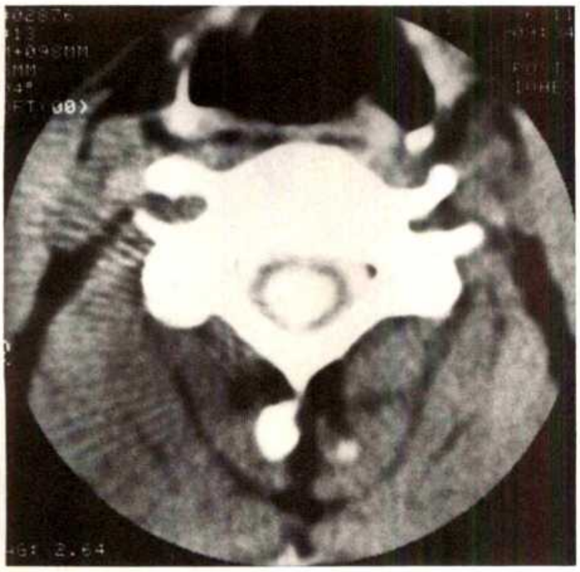


FIG. 4.

Computed myelography (at 24 h) shows dense opacification of a syrinx.

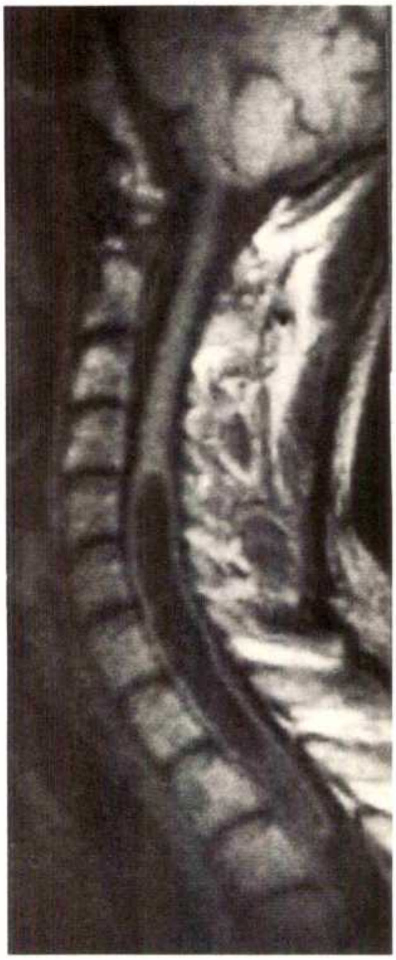


FIG. 5.

Magnetic resonance image (T_1-weighted) in the midline sagittal plane. Syringomyelia is demonstrated above the fundus of the intraspinal arachnoid cyst.

ACKNOWLEDGMENTS

We thank Dr A. N. Gale, consultant neurologist, Dr D. N. Phear, consultant physician, and Mr K. W. Lindsay, consultant neurosurgeon, for permission to publish details of a patient under their care.

REFERENCES

HANEY, A., STILLER, J., ZELNIK, N. & GOODWIN, L., 1985. Association of post traumatic spinal arachnoid cyst and syringomyelia. *CT—Journal of Computed Tomography, 9*, 137–140.

KENDALL, B. E., VALENTINE, A. R. & KEIS, B., 1982. Spinal arachnoid cysts: clinical and radiological correlation with prognosis. *Neuroradiology, 22*, 225–234.

MCLEAN, D. R., MILLER, J. D. R., ALLEN, P. B. R. & ALI EZZEDDIN, S., 1973. Post traumatic syringomyelia. *Journal of Neurosurgery, 39*, 485–492.

1987, *The British Journal of Radiology*, *60*, 1026–1028

Case reports

Radiographic appearance of frontal osteomyelitis in two patients with extradural abscess

By A. M. Belli, F.R.C.R., C. J. Dow, M.R.C.P., F.R.C.R. and *P. Monro, B.Sc., M.D., F.R.C.P.

Department of Radiology, St James' Hospital and *Department of Neurology, Atkinson Morley's Hospital, London

(*Received July 1986 and in revised form January 1987*)

Frontal osteomyelitis and extradural abscess formation are recognised complications of frontal sinusitis and can be life-threatening. The incidence of these complications has decreased since the introduction of antibiotics. The radiographic changes can be subtle and may be overlooked.

Two cases are presented which showed a similar, unusual appearance on skull radiographs. The diagnosis was confirmed on computed tomography (CT).

CASE REPORTS

Case 1

A 15-year-old girl of West Indian origin gave a 1-year history of intermittent frontal headaches. In the last 3 months these had been associated with a tender swelling on her forehead. Her mother had noticed loss of memory and drowsiness but no personality change.

On examination she had a prominent, slightly tender forehead. There was no neurological deficit and she was apyrexial.

Investigations showed she had a variant of sickle-cell disease and a normal leucocyte count. Skull radiographs showed marked thickening of the frontal bone with a transradiant area in the midline. There was also loss of definition of the margin of the right frontal sinus and hazy opacification of that sinus (Fig. 1).

A CT scan showed bilateral thickening of the frontal bones. Behind this was a well defined extradural collection of fluid with a thickened wall which enhanced with contrast. A frontal craniectomy was performed and a chronic extradural abscess excised. The frontal bones were markedly thickened. Anaerobic streptococci were cultured from the pus and the patient was treated with appropriate antibiotics.

Case 2

A 14-year-old asthmatic boy of West Indian origin complained of a 5-month history of persistent nasal discharge with occasional frontal headaches. On examination he was apyrexial and had no neurological deficit. Investigations showed an erythrocyte sedimentation rate of 70 mm/h but no leucocytosis. He did not have sickle-cell disease.

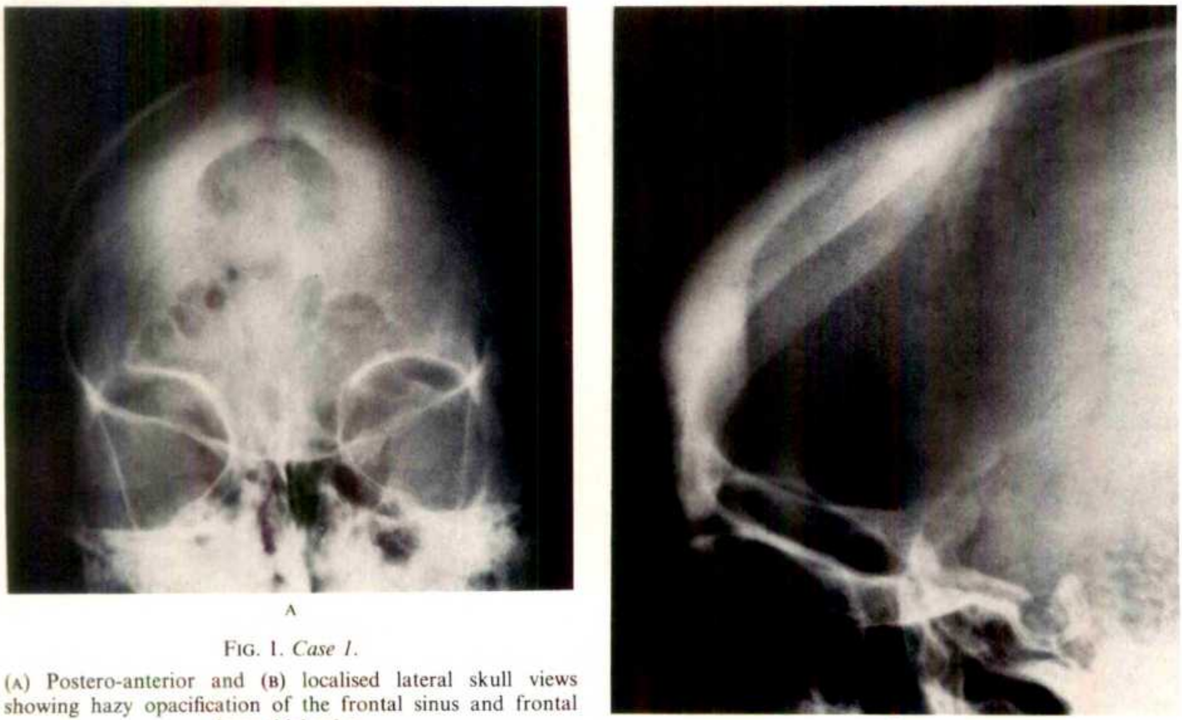


FIG. 1. *Case 1.*

(A) Postero-anterior and (B) localised lateral skull views showing hazy opacification of the frontal sinus and frontal bone thickening.

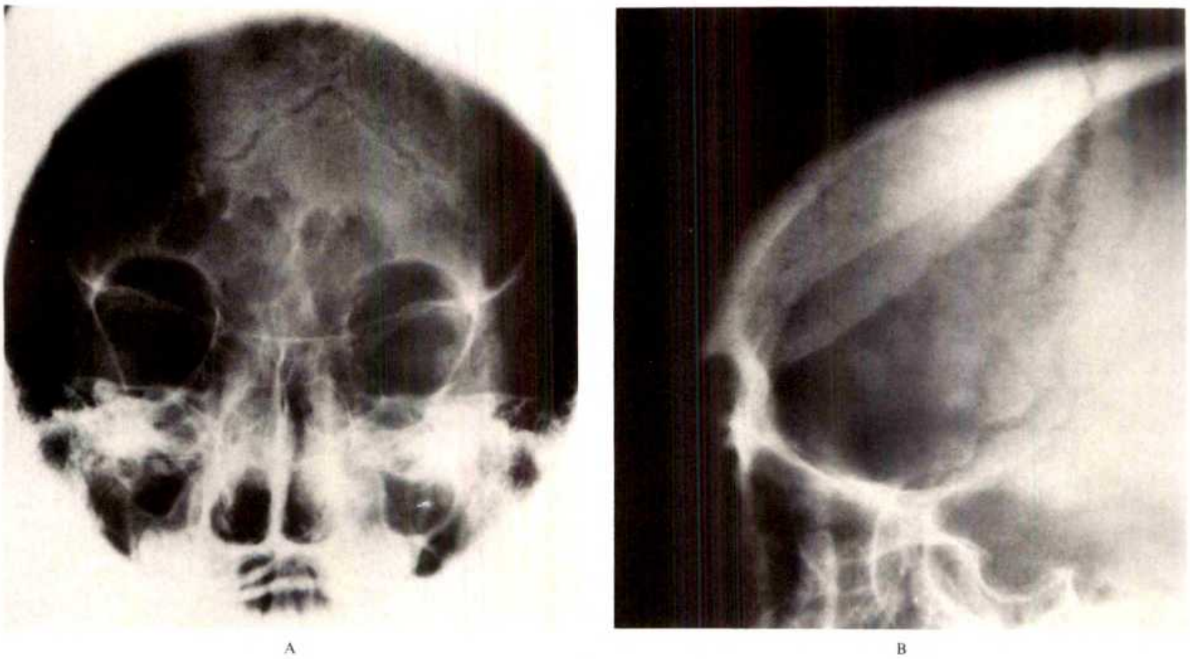


FIG. 2. *Case 2.*

(A) Coned postero-anterior sinus view and (B) localised lateral skull view showing sinus opacification, frontal bone thickening and features of raised intracranial pressure. (Diastasis of coronal suture and erosion of dorsum sellae.)

Radiographs of the paranasal sinuses showed opacification of all the sinuses, and evidence of chronic raised intracranial pressure with changes in the dorsum sellae and diastasis of the coronal suture. In addition, the frontal bones showed marked thickening with an appearance similar to those in Case 1 (Fig. 2). A CT scan showed a frontal extradural collection which demonstrated contrast enhancement of the wall, similar in appearance to that described in Case 1 (Fig. 3).

At operation the frontal sinuses were explored, bilateral antrostomies and ethmoidectomy were performed. Anaerobic streptococci were cultured from pus and he was treated with appropriate antibiotics. The patient was unfortunately lost to follow-up.

DISCUSSION

Intracranial complications of frontal sinusitis are unusual since the advent of antibiotics. Radiographic evidence of frontal sinusitis, with or without skull osteomyelitis, when associated with unrelenting headache, fever and leucocytosis may suggest an intracranial complication (Handel et al, 1974).

Extradural abscesses are most often complications of frontal sinusitis or middle-ear infection and tend to affect people aged between 10 and 20 years (Rice et al, 1980). They develop as an insidious process with minimal neurological signs since the collection is rarely

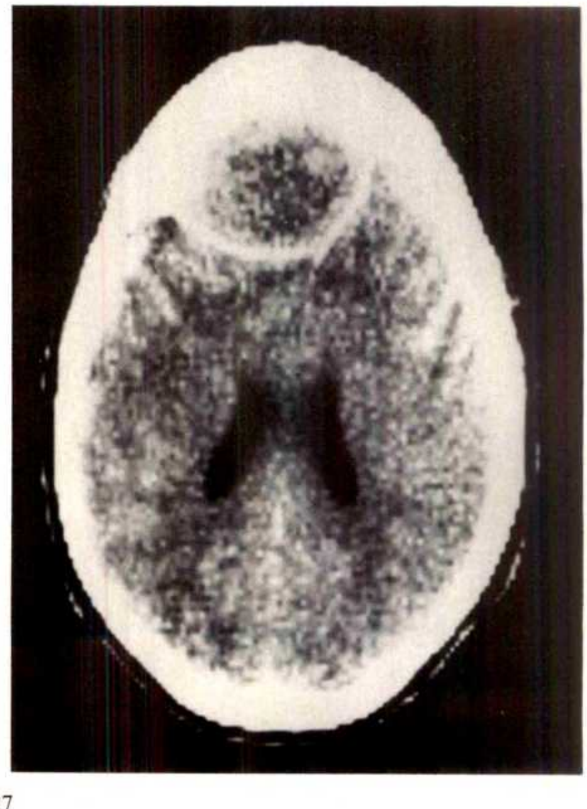


FIG. 3. *Case 2.*
A CT scan showing extradural abscess.

1987, *The British Journal of Radiology*, *60*, 1028–1029

large enough to produce localising signs. The distended dura is painful and sensitive and the patient may complain of headaches but otherwise may not be ill. The CT appearance of an extradural collection is that of a localised, lenticular space-occupying lesion. A subdural collection spreads more and produces a flatter lesion.

The pathway of infection is from the frontal sinus to the veins of the mucosa and thence to the diploic veins from where infection spreads intracranially by septic thrombophlebitis. Direct extension can also occur through congenital defects in the posterior plate of the frontal sinus (Mohr & Nelson, 1982). Focal areas of osteomyelitis also provide direct routes of access to the opposite frontal sinus, orbit or intracranially. If the infection forms a localised subperiosteal abscess, this causes a soft, tender mass (Pott's puffy tumour).

In both patients CT demonstrated extradural abscesses and frontal bone hyperostosis. Each patient had radiological evidence of sinusitis and the skull radiographs showed the same features, the thickened frontal bone forming a dense rim around a relatively lucent centre. In patients with frontal sinusitis this appearance should suggest the possibility of an intracranial complication.

The differential diagnosis of such an appearance includes an epidermoid tumour. This produces a sharply demarcated bone defect on radiographs with a well defined and sometimes sclerotic margin. This was considered in Case 1 as the subtle changes of frontal sinusitis were not originally appreciated.

Summary

Extradural abscess can be a complication of frontal sinusitis. The chronicity of this condition can give rise to extreme frontal hyperostosis which can be an important radiological sign in a condition which may be clinically obscure.

Acknowledgment

Our thanks are due to the photographic department of St James' Hospital.

REFERENCES

Handel, S. F., Klein, W. C. & Kim, Y. W., 1974. Intracranial epidural abscess. *Radiology*, *111*, 117–120.

Mohr, R. M. & Nelson, L. R., 1982. Frontal sinus ablation for frontal osteomyelitis. *Laryngoscope*, *92*, 1006–1015.

Rice, D. H., Fishman, S. M., Barton, R. T., Hutcherson, R. & Eichel, B. S., 1980. Cranial complications of frontal sinusitis. *American Family Physician*, *22*, 145–149.

Demonstration of a matrix calculus using computed tomography

By P. W. Sheppard, M.B., B.S., F.R.C.R. and *F. E. White, M.R.C.P., F.R.C.R.

Department of Radiology, Freeman Hospital, Newcastle-upon-Tyne, and *Department of Radiology, Newcastle General Hospital, Newcastle-upon-Tyne

(*Received December 1986*)

Computed tomography (CT) may help to determine the cause of radiolucent filling defects in the renal collecting system. Previous reports have all emphasised the relatively high attenuation values of non-opaque calculi when seen by CT (Segal et al, 1978; Pollack et al, 1981; Parienty et al, 1982). This has been an important feature in distinguishing calculi from other filling defects such as old blood clot and transitional-cell carcinoma. We present a case where an intrapelvic filling defect of relatively low attenuation on CT was subsequently shown to be a matrix calculus.

Case Report

A 70-year-old woman developed acute right-sided renal colic and became anuric. The left kidney had been removed 6 months previously for hydronephrosis secondary to a stone. An intravenous urogram (IVU) showed an obstructed right collecting system, with a small calculus in the lower ureter. Percutaneous nephrostomy was performed and nephrostomy drainage was continued for 2 months, after which the ureteric stone passed spontaneously. Two weeks after removal of the nephrostomy drain a repeat IVU showed a smooth, 1.7 cm radiolucent filling defect in the pelvis of the right kidney. At this time the patient was asymptomatic and otherwise well. The serum urate was slightly raised at this time (0.4 mmol/l). The urine was sterile. Ultrasound examination did not demonstrate the filling defect, and the patient proceeded to CT. The right kidney was scanned at 1 cm intervals before and at 0.5 cm intervals after intravenous contrast. No area of high attenuation was seen in the renal pelvis, but there was the suggestion of a mass of soft-tissue density situated posteriorly in the renal pelvis (Fig. 1) which was clearly seen on the post-contrast scan (Fig. 2). The filling defect measured 16 HU on the unenhanced scan, and 37 HU after contrast. The adjacent psoas muscle measured 43 HU both before and after contrast. Because of the angular shape it was felt the filling defect was unlikely to be tumour, and that debris or a matrix stone was more likely, particularly in view of the history of previous stones.

Right retrograde ureteroscopy was then performed and a freely mobile, white, irregular calculus was seen. At subsequent percutaneous nephrolithotomy a soft matrix calculus was removed in fragments. The stone was composed of pro-

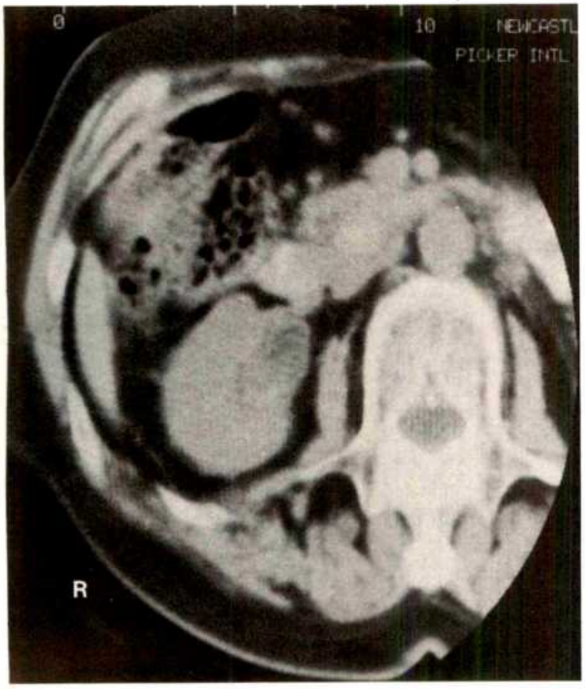


FIG. 1.

Unenhanced scan shows poorly defined mass of soft-tissue density in posterior renal pelvis.

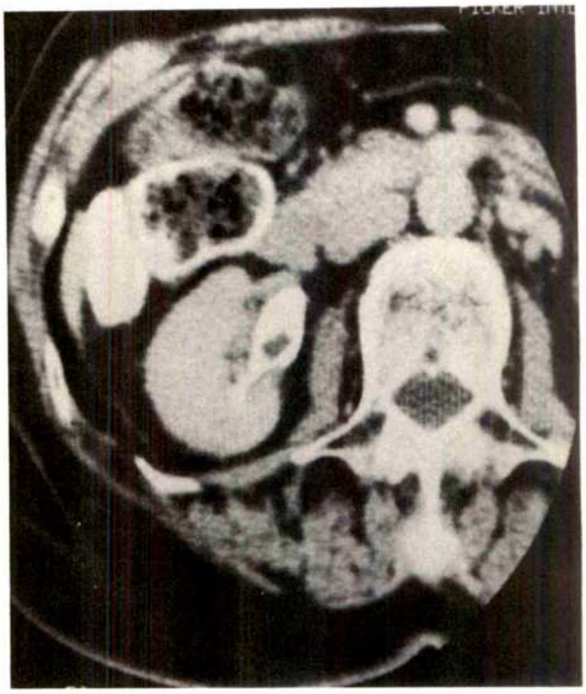


FIG. 2.

Contrast in renal pelvis surrounds an angular filling defect of low attenuation.

teinaceous material and biochemical analysis by infra-red spectroscopy showed no mineral content. The patient made an uneventful recovery.

DISCUSSION

Matrix calculi are uncommon and are usually associated with urinary stasis or infection. They may have a crystalline colloid content, making them gritty, or have a soft, putty-like consistency (Pyrah, 1979). Most radiolucent calculi are composed either of uric acid or contain only very small amounts of calcium in their stroma. These two features render them identifiable by CT and by ultrasound examination (Pollack et al, 1978). Previous reports have all emphasised the high attenuation values of uric acid and other "non-opaque" calculi on CT, ranging from 70 HU to 402 HU (Parienty et al, 1982). The case presented is of a matrix stone with no mineral content which was not identifiable at sonography, presumably because it was too soft to produce acoustic shadowing. It also had a low attenuation on CT and could have been mistaken for a soft-tissue tumour.

The apparent increased attenuation after contrast is considered to be due to partial volume with the surrounding dense contrast in the renal pelvis. The attenuation, however, remained lower than that of adjacent psoas muscle, a factor against it being a tumour. In this case scans in different positions were not done, but might have shown the filling defect to be mobile within the pelvis.

The possibility of a matrix calculus should be considered, together with soft-tissue tumours such as transitional-cell carcinoma, benign polypoid lesions and old haematoma, when a low-attenuation filling defect is seen within the renal collecting system on CT.

ACKNOWLEDGMENT

We wish to thank Mr P. H. Powell for permission to report this case.

REFERENCES

PARIENTY, R. A., DUCELLIER, R., PRADEL, J., LUBRANO, J.-M., COQUILLE, F. & RICHARD, F., 1982. Diagnostic value of CT numbers in pelvicalyceal filling defects. *Radiology, 145*, 743–747.

POLLACK, H. M., ARGER, P. H., GOLDBERG, B. B. & MULHOLLAND, S. G., 1978. Ultrasonic detection of non-opaque renal calculi. *Radiology, 127*, 233–237.

POLLACK, H. M., ARGER, P. H., BANNER, M. P., MULHERN, C. B. & COLEMAN, B. G., 1981. Computed tomography of renal pelvic filling defects. *Radiology, 138*, 645–651.

PYRAH, L. N., 1979. *Renal Calculus.* (Springer, Berlin), pp. 22–26.

SEGAL, A. J., SPATARO, R. F., LINKE, C. A., FRANK, I. N. & RABINOWITZ, R., 1978. Diagnosis of non-opaque calculi by computed tomography. *Radiology, 129*, 447–450.

1987, *The British Journal of Radiology*, *60*, 1030–1031

Case reports

Appendix mass in AIDS?

By S. H. Lee, F.R.C.S., M. A. Hall-Craggs, M.A., M.R.C.P. and W. R. Lees, F.R.C.R.

Department of Radiology, The Middlesex Hospital, London

(*Received December 1986*)

We report the case of a male homosexual known to have the human immunodeficiency virus (HIV) and who presented with an acutely painful mass in the right iliac fossa. The initial clinical diagnosis was of an appendix abscess but subsequent investigation and ultimately laparotomy proved this to be a tuberculous ileal mass.

CASE REPORT

A 30-year-old white English homosexual presented with a 2-week history of pain in the right iliac fossa, fever and general malaise. On examination he was found to have a tender mass in the right iliac fossa and a provisional diagnosis of an appendix abscess was made. In the past he had had several sexually transmitted infections including hepatitis B, syphilis, gonorrhoea, and genital herpes. He had not travelled outside Europe but had recently been found positive for the HIV using the standard Wellcozyme test.

Ultrasonography showed the mass to be thickened small-bowel loops with associated local lymphadenopathy. Computed tomography (CT) confirmed these findings and clearly demonstrated several contrast medium-filled loops of thick-walled ileum (Figs 1, 2) and enlarged mesenteric and iliac nodes (Fig. 3). The liver and spleen were normal and there was no ascites.

The differential diagnosis derived from these studies was of small-bowel tuberculosis, lymphoma, Kaposi's sarcoma and Crohn's disease.

The patient's condition progressively deteriorated and ultimately laparotomy was performed, which confirmed the CT findings. Biopsy specimens were taken from iliac and mesenteric nodes, but the diseased small bowel was not resected.

Microscopy revealed acid-fast bacilli and specimen culture grew *Mycobacterium tuberculosis* which was fully drug-sensitive. Histology showed caseating granuloma and the patient responded to antituberculous drugs. Chest radiographs were normal. Several weeks later he was readmitted with cerebral toxoplasmosis.

DISCUSSION

Up to December 1986, there had been 599 reported cases of AIDS in the United Kingdom (UK) with 297 deaths since 1982. Of people infected with HIV, 43%

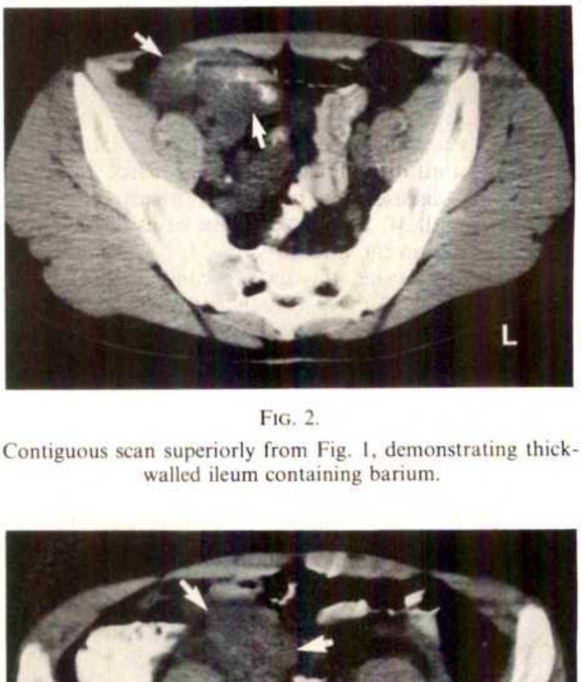


FIG. 2.

Contiguous scan superiorly from Fig. 1, demonstrating thick-walled ileum containing barium.

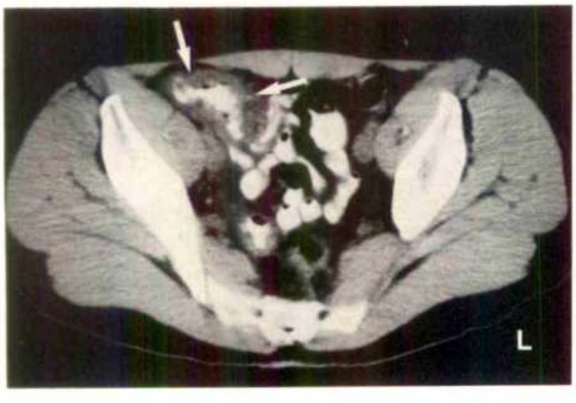


FIG. 1.

A CT scan through the mid-pelvis. Arrows demonstrate loops of ileum with thickened walls containing barium in the right iliac fossa, seen only on delayed films.

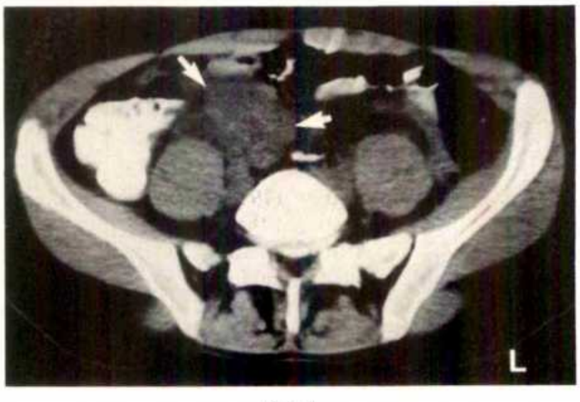


FIG. 3.

A CT scan through the upper pelvis. Arrows demonstrate a lobulated mass of the enlarged mesenteric lymph nodes.

1987, *The British Journal of Radiology*, *60*, 1031–1033

will develop AIDS within 3 years (Hunter & De Gruttola, 1986). The syndrome has protean manifestations which include opportunistic infections (Gelb & Miller, 1986), malignancy, and lymphadenopathy syndrome (Moon et al, 1984).

There have been several reports of abdominal tuberculosis and the majority have been infected with the atypical organism *Mycobacterium avium-intracellulare* (MAI) (Zakowski et al, 1982). Any part of the alimentary tract may be affected (Brody et al, 1986), but the most common site is the ileocaecal region, as in this case.

The CT findings of ascites, localised peritoneal, mesenteric and bowel-wall thickening with enlarged draining nodes in abdominal tuberculosis are strongly suggestive of the diagnosis but are non-specific (Epstein & Mann, 1982). Recent reports describe the varied CT findings in both typical and atypical mycobacterium in patients with AIDS and other groups at risk (Hulnick et al, 1985; Nyberg et al, 1985). They include adenopathy affecting both retroperitoneal and/or mesenteric nodes in all patients, many with low-attenuation centres suggesting necrosis. Most have splenomegaly and/or hepatomegaly containing focal mass lesions. Other common findings are ascites, bowel-wall thickening and low-attenuation abscesses.

Infections with MAI are usually resistant to the standard antituberculous drugs, are associated with pulmonary disease, and have a worse prognosis than infections with *M. tuberculosis*. Few cases of MAI have been reported in the UK.

We have reported this case because the presenting complaint of a right iliac fossa mass is unusual in a patient with AIDS and has not been recorded previously. It is important to consider tuberculosis in the differential diagnosis which includes Kaposi's sarcoma and bowel lymphoma. The necessity of obtaining biopsy material is stressed and a fine-needle biopsy would have been appropriate, under either CT or sonographic control, and is a rapid way of making a specific diagnosis of tuberculosis.

REFERENCES

BRODY, J. M., MILLER, D. K., ZEMAN, R. K., KLAPPENBACH, R. S., JAFFE, M. H., CLARK, L. R., BENJAMIN, S. B. & CHOYKE, P. L., 1986. Gastric tuberculosis: a manifestation of acquired immunodeficiency syndrome. *Radiology*, *159*, 347–348.

EPSTEIN, B. M. & MANN, J. H., 1982. CT of abdominal tuberculosis. *American Journal of Roentgenology*, *139*, 861–866.

GELB, A. & MILLER, S., 1986. AIDS and gastroenterology. *American Journal of Gastroenterology*, *81*, 619–622

HULNICK, D. H., MEGIBOW, A. J., NAIDICH, D. P., HILTON, S., CHO, K. C. & BALTHAZAR, E. J., 1985. Abdominal tuberculosis: CT evaluation. *Radiology*, *157*, 199–204.

HUNTER, D. J. & DE GRUTTOLA, V., 1986. Estimation of the risk of outcomes of HTLV-III infection (letter) *Lancet*, *i*, 677.

MOON, K. L., JR, FEDERLE, M. P., ABRAMS, D. I., JOLBERDING, P. & LEWIS, B. J., 1984. Kaposi sarcoma and lymphadenopathy syndrome: limitations of abdominal CT in acquired immunodeficiency syndrome. *Radiology*, *150*, 479–483.

NYBERG, D. A., FEDERLE, M. P., JEFFREY, R. B., BOTTLES, K. & WOFSY, C. B., 1985. Abdominal CT findings of disseminated *Mycobacterium avium-intracellulare* in AIDS. *American Journal of Roentgenology*, *145*, 297–299.

ZAKOWSKI, P., FLIGIEL, S., BERLIN, G. W. & JOHNSON, B. L., 1982. Disseminated *Mycobacterium avium-intracellulare* infection in homosexual men dying of acquired immunodeficiency. *Journal of the American Medical Association*, *248*, 2980–2982.

Sclerosing stromal tumour of the ovary

By *Nobuko Kawamura, M.D., Itsuma Kamoi, M.D. and †Ritsuo Shigyo, M.D.

Departments of Radiology and †Obstetrics and Gynecology, Kyushu Chuo Hospital, Fukuoka, Japan

(*Received January 1987*)

Chalvardjian and Scully (1973) first described the sclerosing stromal tumour of the ovary as a rare, benign ovarian neoplasm. Although over 60 further cases have since been reported (Chalvardjian & Scully, 1973; Gee & Russel, 1979; Zhang, 1980; Tang & Liu, 1982; Young & Scully, 1982; Martinelli et al, 1983), so far no findings on computed tomography (CT) have been reported. We present the CT findings from a sclerosing stromal tumour and review previously reported cases.

CASE REPORT

A 14-year-old girl with a lower abdominal mass and irregular menses was referred to Kyushu Chuo Hospital. On physical examination, a huge, non-tender pelvic mass was palpated. Tumour markers including CA-125, AFP and CEA were 100 U/ml, negative and 1.10 ng/ml respectively. A CT scan showed a large cystic mass 20 cm in diameter at the widest point, comprising a large cystic element, an irregular cyst wall

---

*Present address: Nobuko Kawamura, Department of Radiology, Faculty of Medicine, Kyushu University, Maidashi 3-1-1, Higashi-ku, Fukuoka-shi, 812, Japan. Tel. 092 (641) 1151, ext. 2595.

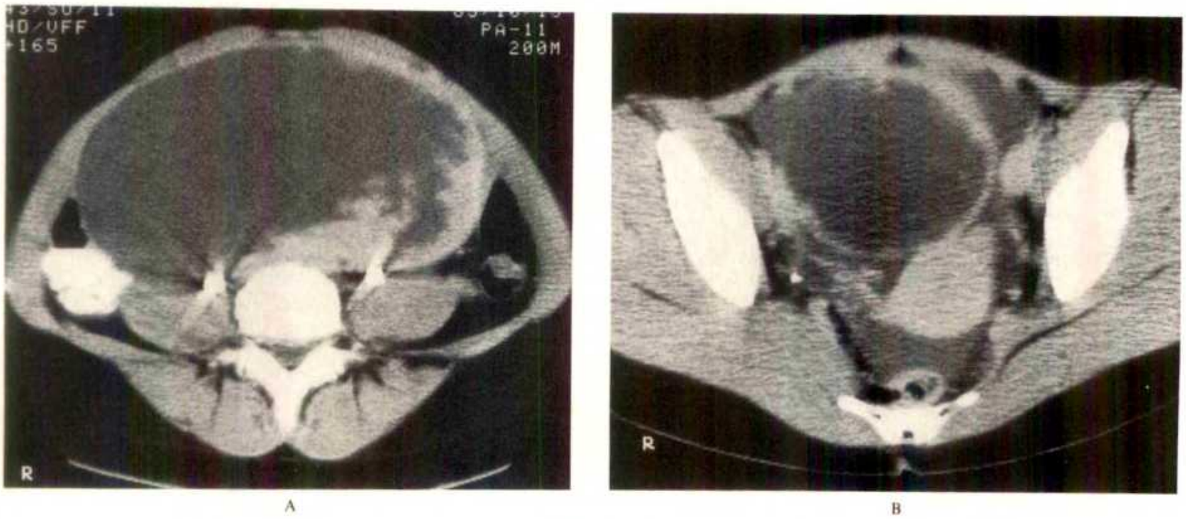


FIG. 1.

Enhanced CT scan of the pelvis. (A) A large cystic mass can be seen in the pelvis. A small area of the irregular septate portion is shown on the left side of the mass. (B) Ascites can be seen around the uterus and ovarian cystic mass.

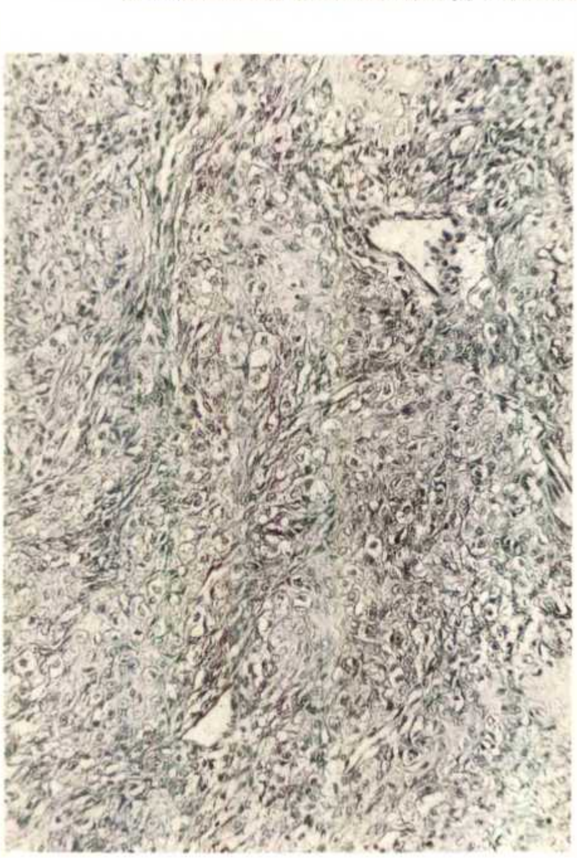


FIG. 2.

A cellular area is shown around cells with clear cytoplasm, spindle-shaped cells, dense collagen formation and well developed vascularity (H & E × 200).

and small solid components. Their enhanced CT values were about 20 HU, 80 HU and 90 HU respectively (Fig. 1A). Also, a small fluid collection was noted in the pelvic cavity (Fig. 1B). The pre-operative diagnosis was of a malignant ovarian tumour, possibly an ovarian cystoadenocarcinoma with ascites.

At surgery, a huge, greyish-white to yellow, ovoid mass with a smooth surface involving the left ovary was removed. The right ovary was grossly normal. The mass was cystic with a large amount of serous fluid. Its wall was gelatinous and irregular in thickness and small solid parts containing scattered yellow foci were found. Microscopically, the tumour was composed of cellular areas and oedematous or fibrous stroma forming a typical pseudolobular pattern. The cellular areas consisted of round cells with clear cytoplasm occasionally positive for fat stain, spindle-shaped cells with collagen fibres and well developed vascularity (Fig. 2). Sclerosing stromal tumour of the ovary was confirmed.

DISCUSSION

Sclerosing stromal tumour of the ovary was first described by Chalvardjian and Scully in 1973 as a distinct subtype within the thecoma–fibroma group, which differs from other stromal tumours both clinically and pathologically. To date, over 60 cases have been reported and over 70% of patients are under 30 years old. This is different from other stromal tumours such as fibroma, thecoma and lipid-cell tumour, whose peak incidence is in the 5th and 6th decades. Two thirds of patients complain of either abnormal uterine bleeding or menstrual irregularity and it is of interest that in five cases the patient became pregnant soon after removal of the tumour (Gee & Russel, 1979; Tang & Liu, 1982). Four cases were studied by hormonal and ultrastructural analysis and considered to have hormonal activity (Damjanov et al, 1975; Tang & Liu, 1982; Yuen et al, 1982; Martinelli et al, 1983). Macroscopically, they are greyish-white to yellow tumours with a smooth surface, varying in diameter from 2 cm to 17 cm at the widest point. Many are solid lesions containing small cysts and only two cases were reported as primarily cystic tumours (Gordon & Slotnick, 1983; Hsu et al, 1983). Ascites was reported in only one previous case (Tsukamoto et al, 1976).

Computed tomography has been widely used for preoperative examination of ovarian tumours but differentiation between benign and malignant lesions has been difficult in some cases. Findings on CT that suggest malignancy include: a multiloculated cystic mass, thick septation, especially with coexistent solid nodules, a complex mass inseparable from the uterus, and ascites (Lewis et al, 1982; Yamauchi, 1984). According to these criteria, the CT findings in our case were considered to be those of malignancy. However, benign ovarian tumours associated with ascites do exist, although they are rare (Meig's syndrome).

Samanth and Black (1970), who studied 10 cases of benign stromal tumours with ascites, reported that 14.2% of ovarian benign stromal tumours were associated with ascites and 21% were cystic. Also, Young and Scully (1982) pointed out that about 40% of fibromas over 10 cm in diameter at the widest point are associated with ascites.

When assessing an ovarian tumour with ascites, one should list stromal tumour in the differential diagnosis. If, in addition, it occurs in young women with metrorrhagia and infertility, then a sclerosing stromal tumour should be regarded as a stronger possibility.

REFERENCES

CHALVARDJIAN, A. & SCULLY, R. E., 1973. Sclerosing stromal tumors of the ovary. *Cancer, 31*, 664–670.

DAMJANOV, I., DROBNJAK, P., GRIZEL, V. & LONGHINO, N., 1975. Sclerosing stromal tumors of the ovary. A hormonal and ultrastructural analysis. *Obstetrics and Gynecology, 45*, 675–679.

GEE, D. C. & RUSSEL, P., 1979. Sclerosing stromal tumor of the ovary. *Histopathology, 3*, 367–376.

GORDON, C. I. & SLOTNICK, E., 1983. Sclerosing stromal tumor of ovary: report of a case. *Journal of the American Osteopathic Association, 83*, 163–166.

HSU, C., MA, L. & MAK, L., 1983. Sclerosing stromal tumor of the ovary. *International Journal of Gynecological Pathology, 2*, 192–200.

LEWIS, E., ZORNOZA, J., JING, B. S., CHUANG, V. P. & WALLACE, S., 1982. Radiologic contribution to the diagnosis and management of gynecologic neoplasms. *Seminars in Roentgenology, 17*, 251–268.

MARTINELLI, G., GOVONI, E., PILERI, S., GRIGIONI, F. W., DOGLIONI, C. & PELUSI, G., 1983. Sclerosing stromal tumor of the ovary. A hormonal, histochemical and ultrastructural study. *Virchows Archiv A, 402*, 155–161.

SAMANTH, K. K. & BLACK, W. C., 1970. Benign ovarian stromal tumors associated with free peritoneal fluid. *American Journal of Obstetrics and Gynecology, 107*, 538–545.

TANG, M. & LIU, T., 1982. Ovarian sclerosing stromal tumors, clinicopathologic study of 10 cases. *Chinese Medical Journal, 95*, 186–190.

TSUKAMOTO, N., NAKAMURA, M. & ISHIKAWA, H., 1976. Sclerosing stromal tumor of the ovary. *Gynecologic Oncology, 4*, 335–339.

YAMAUCHI, I., 1984. Role of X-ray CT in diagnosis of ovarian tumor. *Actaetrica Obstet Gynaecologica Japonica, 36*, 785–794 (in Japanese).

YOUNG, R. H. & SCULLY, R. E., 1982. Ovarian sex cord stromal tumors. Recent progress. *International Journal of Gynecological Pathology, 1*, 101–123.

YUEN, B. H., ROBERTSON, D. I., CLEMENT, P. B. & MINCEY, E. K., 1982. Sclerosing stromal tumor of the ovary. *Obstetrics and Gynecology, 60*, 252–256.

ZHANG, J., 1980. Sclerosing stromal tumor of the ovary. Report of 3 cases. *Chinese Journal of Oncology, 2*, 76–78.

Book reviews

Ultrasound Atlas: Real-Time Ultrasound Imaging in Internal Medicine. By Hagen Weiss and Adelheid Weiss, pp. 416 + index, 1986 (VCH Verlagsgesellschaft mbH, Weinheim), DM 135.
ISBN 3-527-15223-7 (Weinheim)
0-89573-452-4 (Deerfield Beach)

To write an adverse review of a textbook is both difficult and discomfiting for the reviewer, particularly when it is obvious that the book represents the culmination of a considerable amount of genuinely useful work. Unfortunately, an atlas of any type is only as good as its images and the quality of this otherwise very commendable work is diminished by its poor illustrations. The contents of this atlas reflect the considerable ultrasound experience of the authors, who have produced 652 cases of interest covering virtually all the sonographically accessible regions and niches of the body. Not surprisingly, the majority of the examples relate to the abdomen but there are also short sections which include the skin, breast and testes. There is virtually no neurosonology or obstetric ultrasound.

Each of the cases is illustrated on one page by a small sonogram adjacent to a line diagram, together with further annotation indicating the position of the transducer. This method is most successful and without the line diagram and orientation, the display of many of the images would be uninterpretable. On the page facing the illustrations there is a short description of the clinical and ultrasound features demonstrated on the image. This format is attractive and the accompanying text is brief and pertinent; the translation from the original German is flawless. Each section is generously referenced.

Unfortunately, however, it is the image quality which prevents recommendation of this otherwise useful book. Virtually all the images have been produced by linear-array machines, which are listed in the first chapter. All of these machines would be considered somewhat dated nowadays. It might also be argued that linear-array scans are less appropriate than sector images for the display of abnormal anatomy and certainly the small size of the images and their reduced field of view does nothing for the quality of the illustrations.

D. M. KING

Atlas of Radiologic Anatomy, 4th edit. By Lothar Wicke (translated and edited by Anna N. Taylor) pp. xvi + 288, 1987 (Urban & Schwarzenberg, Munich), DM 48.
ISBN 3-541-72114-6 (Munich)
0-806-72114-6 (Baltimore)

The book covers a wide area of radiological anatomy which is applicable to radiological practice today. The prints are of the very highest quality and the line diagrams are excellent, with very clearly labelled anatomical details. The book reads well, there is very little repetition and has been very successfully translated from the German. The layout is particularly good.

One criticism would be that the authors have deliberately omitted ultrasonography so that there are no ultrasound images in this edition. This I feel is a mistake, as ultrasound anatomy is extremely important. There are no computed tomography (CT) images of the neck, chest or pelvis, and I think this is another area of weakness. Some of the CT scans are a little over-coned and exclude peripheral anatomy that may have been useful. A mildly irritating feature is that in some instances the images have been rotated and set at 90° to the text, so that the book has to be turned around in order to read them. I also feel that the introduction, history and the brief description of radiation and imaging techniques could be excluded.

On balance, this is a good book, but I am not sure that it adds any extra anatomy to already existing tomes.

P. GISHEN

Endourology, Principles and Practice. Ed. by A. D. Smith, W. R. Casteñrfs-Xuñiga and J. G. Bronson, pp. xvi + 416, 1986 (Georg Thieme Verlag, Stuttgart), DM168.
ISBN 3-13-665701-2 (Stuttgart)
0-86577-135-9 (New York)

The dramatic advances in interventional radiology of the urinary tract over the past few years has caused great clinical interest amongst both radiologists and urologists, totally changed the management of many conditions, mainly urinary stone disease, and seemingly spurred numerous authors into print about the subject! Perhaps it is not surprising: the subject continues to expand quite rapidly with new technological developments, especially in the field of extracorporeal shockwave lithotripsy where manufacturers are falling over each other to produce second-generation and third-generation lithotripters at an alarming rate.

The editors state in the preface that they make no pretence in covering the whole subject of endourology and as far as this book is concerned, endourology appears to cover interventional radiology done by the radiologist alone, interventional radiology done by both urologists and radiologists together with imaging control, and percutaneous techniques practised by the urologist alone. The book is in six sections. Part 1 deals with radiation protection in endourology. Part 2 deals with endourology of the kidney, mainly percutaneous stone removal, the techniques of lithotripsy, chemolysis of urinary stones and angiography of the kidney. Part 3 deals with the ureter, predominantly the insertion of ureteric stents and the dilatation of ureteric strictures. Part 4 deals with the bladder and urethra and lists 50 potential indications for suprapubic cystostomy! Part 5 deals with the retroperitoneum and the aspiration of lymph nodes and Part 6 with the male genitalia, mainly the treatment of varicoceles and the investigation of priaprism. Each section gives due consideration to the relevant anatomy and goes into some detail of the techniques required to perform such procedures. The pros and cons of the numerous drainage tubes, catheters, stents and dilators are discussed.

There are inevitably gaps, endoscopic ultrasound and the use of lasers in the urinary tract to mention but two. The book is well written and the illustrations are of high standard. Line drawings abound and are useful. In the last year, four books have been published from America on interventional uroradiology and endourology. Inevitably, there is much reduplication of content and indeed some of the contributors are shared between them. There are a few things in this present book that are not covered satisfactorily in previous publications, but any department active in interventional uroradiology procedures needs only one of them. If a department has no book on its shelves related to interventional urology and the management of renal stones specifically, then they should consider this one, as it is the latest in the line. If they already have a book on the subject, I do not think that this book is going to enhance their library.

DAVID RICKARDS

1987, *The British Journal of Radiology*, *60*, 1035–1036

Case of the month

A lump on the thigh

By *Malcolm Crone, F.R.C.R. and Iain Watt, M.R.C.P., F.R.C.R.

Department of Radiodiagnosis, Bristol Royal Infirmary, Bristol BS2 8HW

(*Received March 1987*)

A 50-year-old woman presented with a slightly tender mass on the postero-lateral aspect of her thigh. The mass had been present for approximately 10 years and had slowly increased in size, causing a minor degree of discomfort when sitting on a hard seat.

On examination, a diffuse tender swelling, approximately 5 cm × 3 cm, was present on the postero-lateral aspect of the thigh. Apart from a small melanoma on the postero-lateral aspect of the other thigh, no other abnormality could be found.

Plain radiographs of the femur (Figs 1, 2) revealed a clearly defined, ovoid lucency in the midshaft with a breach of the cortex. A thin rim of sclerosis surrounded this area with a discrete layer of well organised periosteal reaction on the medial aspect of the femur overlying the lesion. A well defined soft-tissue mass lesion could just be delineated. The remainder of the femur was normal and no other similar lesions were found.

A radionuclide scan using $^{99}Tc^{m}$-labelled hydroxymethylene diphosphonate (HMDP) showed a normal perfusion phase. The delayed image outlined a normal femur but increased uptake of the radiopharmaceutical in the soft tissue mass in the postero-lateral aspect of the thigh (Fig. 3). What is your differential diagnosis?

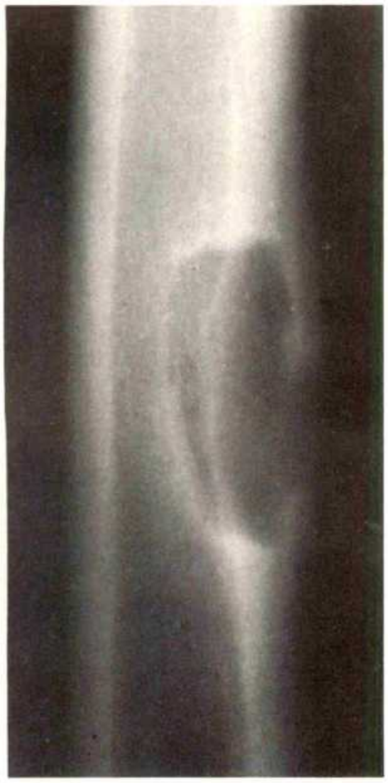


FIG. 1.

Localised lateral view of the midshaft of the femur.

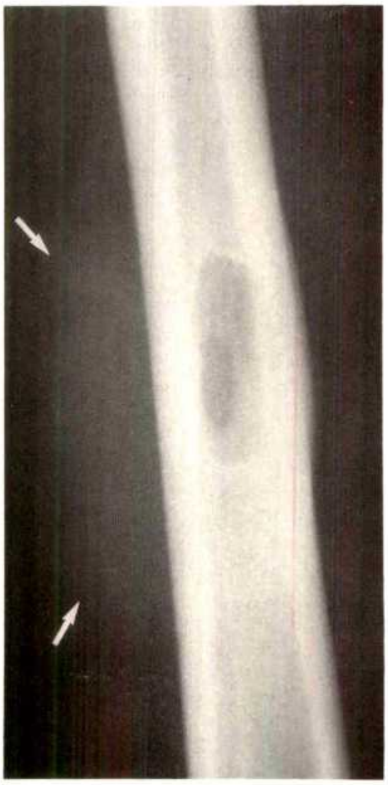


FIG. 2.

Localised antero-posterior view of the same area. Note the soft-tissue mass (arrows).

FIG. 3.

Lateral view from an HMDP bone scan (delayed image). Soft-tissue accumulation shown dorsal to femur (reader's right).

---

*Present address: Department of Radiodiagnosis, Royal Victoria Hospital, Belfast.

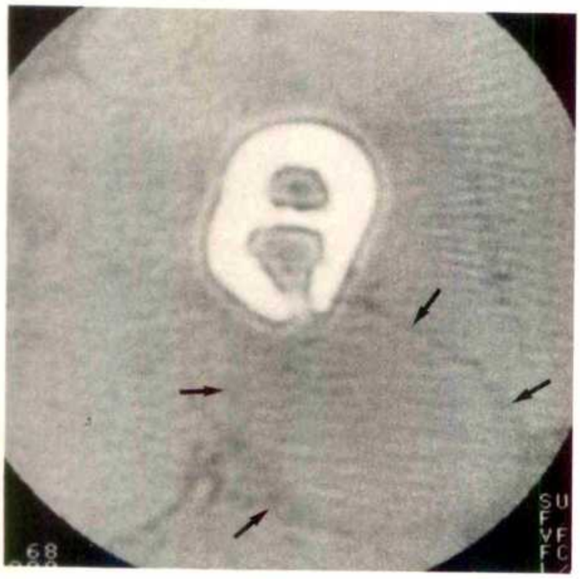


Fig. 4.

A CT scan of left femur: the soft-tissue mass is outlined (arrows).

A differential diagnosis of the given radiological appearances includes histiocytosis (eosinophilic granuloma), Brodie's abscess, a chondroma, fibrous dysplasia, or an intraosseous neurilemmoma or neurofibroma.

A computed tomographic (CT) scan (Fig. 4) confirmed the well defined sclerotic margin of the lucency which communicated with the soft-tissue mass within the muscles of the thigh through a breach in the femoral cortex. The attenuation value of this mass was lower than the surrounding muscles. The absence of calcification militates against a cartilage tumour. Inactivity on the blood-pool phase of the HMDP scan makes an inflammatory lesion most unlikely, as does the well defined soft-tissue mass shown on plain radiographs and CT. Fibrous dysplasia is usually associated with increased avidity on the delayed phase of an HMDP scan, and no soft-tissue mass. Histiocytosis can resemble almost anything but the clues to the correct diagnosis lie in the very non-aggressive radiographic features, suggesting very slow progress, and the obvious "dumb-bell"-like nature of a mass arising at the site of a nutrient canal. Thus an intraosseous neurilemmoma is the most probable radiological diagnosis.

At operation the cavity in the femur was identified and the cloaca communicating with the soft-tissue demonstrated. Gelatinous material was curetted out from the cavity in the bone, which was very clearly marginated. Similar gelatinous material was removed from the cavity within the muscles which also appeared well encapsulated. Histological examination confirmed the radiological diagnosis.

Intraosseous neurilemmoma is an extremely rare tumour which most often occurs in adult females. It is a benign lesion arising from the Schwann cells of the nerve sheath and appearing with the substance of bone. The major innervation of long bones is by peripheral nerves which enter the bone through the nutrient foramina accompanying the nutrient arteries and veins.

The confusion between neurilemmoma and a solitary neurofibroma makes it difficult to ascertain an accurate incidence. However, it accounts for 1% of all neoplasms that arise in bone. Most pathologists agree that the neurilemmoma and solitary neurofibroma are distinct pathological entities, with the neurilemmoma arising from Schwann cells and the neurofibroma from the connective tissue coats.

Microscopically, the tumour tissue is composed of Antoni Type A areas and a lesser number of Antoni Type B areas, with palisaded nuclei of the Schwann cells, fascicles of closely compacted bundles of spindle-shaped fibres and Verocay bodies.

The neurilemmoma may involve bone in three ways: by central involvement, producing rarefaction of the bone (the majority are of this type); a lesion localised to the nutrient canal with production of a dumb-bell-shaped defect; and an extraosseous tumour eroding the bone secondarily (Gordan, 1976; Morrison & Ivins, 1978).

The diagnosis of the soft-tissue tumours in neurofibromatosis using ^{99}Tc^{m}-labelled diethylenetriamine pentaacetic acid (DTPA) has been described (Mandell et al, 1985) and ^{99}Tc^{m}-labelled dimercaptosuccinic acid (DMSA) is also known to accumulate in soft-tissue tumours. Bone-seeking radiopharmaceuticals are known to localise in extraosseous soft-tissue tumours because of calcification and necrosis. One report of a bone-seeking agent accumulating in an extraosseous neurofibroma has been previously made (Nolan, 1974). The present case is thought to be the first case in which the diagnosis of a neurilemmoma has been confirmed by HMDP.

Acknowledgment

The authors wish to thank Mr D. A. P. Ainscow, F.R.C.S., for permission to publish this case.

REFERENCES

Gordan, E. J., 1976. Solitary intraosseous neurilemmoma of the tibia. *Clinical Orthopaedics and Related Research*, *117*, 271–282.

Mandell, G. A., Herrick, W. C., Harcke, H. T., Sharkey, C., Brooks, K. M. & MacEwan, G. D., 1985. Neurofibromas: location by scanning with Tc-99m DTPA. *Radiology*, *157*, 803–806.

Morrison, M. J. & Ivins, J. C., 1978. Benign intraosseous neurilemmoma of the femur. *Skeletal Radiology*, *2*, 179–180.

Nolan, N. G., 1974. Intense uptake of 99m Tc diphosphonate by an extraosseous neurofibroma. *Journal of Nuclear Medicine*, *15*, 1207–1209.

1987, *The British Journal of Radiology*, *60*, 1037–1040 OCTOBER 1987

Short communication

Vascular injury in the mouse rectum after irradiation and cis-diamminedichloroplatinum (II)

By L. Dewit, M.D., Ph.D. and Y. Oussoren

Department of Experimental Radiotherapy, the Netherlands Cancer Institute (Antoni van Leeuwenhoek Huis), Amsterdam, the Netherlands

(*Received April 1987*)

The rectum is a major critical organ in the radiation treatment of pelvic tumours in patients. Late radiation-induced lesions such as ulceration, stenosis, fibrosis and fistulae can be both severe and distressing and are extremely difficult to treat. A better understanding of the pathogenesis of radiation damage in this organ might provide clues towards therapeutic possibilities to prevent such injury. Suitable animal models have been developed (Black et al, 1980; Hubmann, 1981; Terry et al, 1983). It has been suggested that radiation damage in the microvasculature plays a key role in the onset of late damage in the rectum (Trott, 1984; Breiter & Trott, 1986).

The present experiments were aimed at investigating functional changes in the rectal microvasculature at various times after irradiation given with or without cis-diamminedichloroplatinum (II) (c-DDP). These results were related to previously published histological alterations after such treatment (Dewit et al, 1987).

MATERIALS AND METHODS

Mice

Specific pathogen-free inbred male C_3H/nu mice were used at an age of 12–20 weeks and a weight of 29–35 g. They were housed eight to 10 to a cage and fed laboratory chow and water *ad libitum*. Feeding conditions were not changed during observation period.

Irradiations

Unanaesthetised mice were irradiated through one posterior field while immobilised in the prone position in acrylic plastic (Perspex) jigs as previously described (Dewit et al, 1987). The field size was 18.2 mm long by 22.0 mm wide, carefully chosen to include the descending colon, rectum and anus, and yet to exclude all small-bowel loops. X rays were delivered by a Siemens Stabilipan X-ray machine, operating at 250 kV, 15 mA, filter 0.5 mm Cu (half-value layer 1.5 mm Cu), focus–skin distance 35.5 cm, giving an absorbed dose rate of 153 cGy per min at the level of the rectum. Dose variation between three consecutive measurements at the level of the rectum was less than 5%. The dose distribution over the irradiation field, as assessed by film densitometry, varied by less than 2% from the maximum dose. The length of the irradiated rectum within the 95% isodose line and measured from the anal ring was 17.5 ± 0.2 mm (average of 30 mice, 95% confidence limits).

Drug

The c-DDP (Platinol, Bristol-Myers Co.) was used at a concentration of 0.5 mg/ml in normal saline. For the injections, stainless-steel needles with plastic fittings were used instead of aluminium to avoid chemical reaction between the two metal compounds (Bohart et al, 1979).

Experimental design

Groups of six mice received 16 or 22 Gy of X rays alone or 30 min after 6 mg/kg of intraperitoneal c-DDP. The radiation doses were known to cause a 5% and 70% incidence of rectal stenosis within 40 weeks, respectively (Dewit et al, 1987). The drug dose was the maximal tolerated dose within 60 days. The animals were analysed together with age-matched controls using three different functional assays at 5 or 7 days, 3 weeks, 7 weeks and 3, 6 or 9 months after irradiation. For the histological analysis, subgroups of three mice were sacrificed at the same time-points after similar treatment.

Endpoints

The blood volume was measured by labelling mouse red blood cells with ^{51}Cr (^{51}Cr-RBC) using a modification of the technique described by Gray and Frank (1953). Approximately 6 ml of blood was drawn from male C_3H/nu mice and collected in a heparinised sterile tube. Five mCi (185 MBq) ^{51}Cr (sodium chromate, specific activity 23 mCi/ml, Amersham International) was added and the blood was kept at room temperature for 30 min, with occasional gentle shaking. It was then centrifuged for 10 min at 1800 rpm, the supernatant was removed and the red cells were washed twice with sterile normal saline. Thereafter, the packed red cells were resuspended with normal saline to the same total volume as originally collected. Of this suspension 0.1 ml was injected into the mouse tail vein. After 60 min the animal was anaesthetised with ether and 50 μl of blood was collected from the axilla in a plastic tube, weighed and counted in an autogamma counter (Beckham Gamma 8000) for 20 min. A 1 cm segment of the rectum was also excised, weighed and counted.

The vascular permeability was measured with ^{125}I-labelled human serum albumen (^{125}I-HSA, specific activity 50 μCi in 0.1 ml normal saline), injected into the tail vein. Because of a difference in the emission spectrum of ^{51}Cr and ^{125}I, both nuclides could be counted simultaneously and were therefore injected together. The collection procedure was the same for ^{125}I-HSA as for ^{51}Cr-RBC. Assuming no extravasation of red cells, the relative vascular volume was calculated as:

$$\frac{^{51}\text{Cr counts/g tissue}}{^{51}\text{Cr counts/g blood}} \times 100\%$$

Address for reprints: Dr L. Dewit, Antoni van Leeuwenhoekhuis, Plesmanlaan, 121, 1066 CX Amsterdam, The Netherlands.

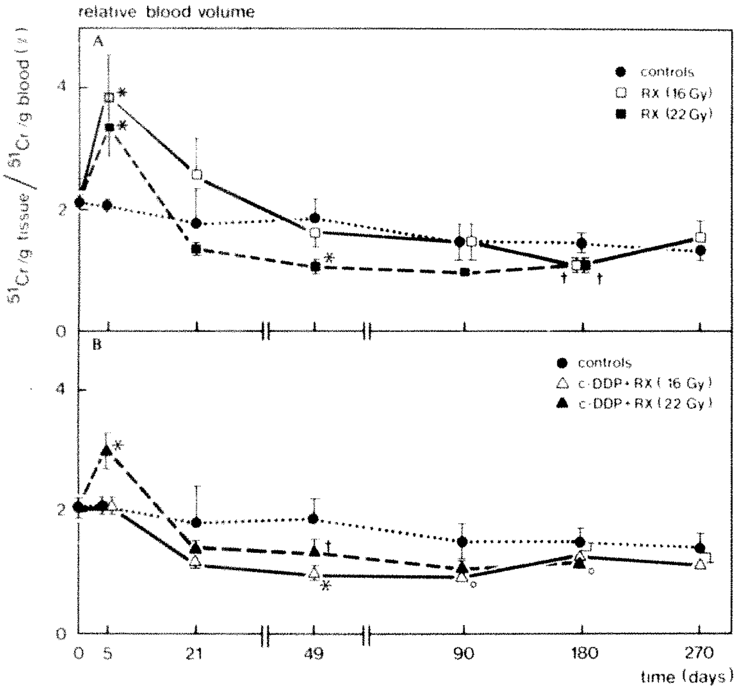


FIG. 1.

Relative blood volume in the rectum versus time after X rays (A) without and (B) with c-DDP (6 mg/kg). Values are the mean of six mice; error bars are ±1 SEM. Marked data points were significantly different from control values: $*p < 0.01$, $+p < 0.02$, $^{\circ}p < 0.05$.

whereas the relative volume accessible to HSA was:

$$\frac{^{125}\text{I counts/g tissue}}{^{125}\text{I counts/g blood}} \times 100\%$$

The latter included the vascular volume plus the interstitial space into which leakage had occurred.

The relative perfusion of the rectum was assessed using the ^{86}Rb extraction assay (Sapirstein, 1958). Rubidium-86 chloride (^{86}RbCl, specific activity of 1 mCi/ml, Amersham International) was injected into the mouse tail vein at a dose of 10 μCi (0.37 MBq) in 0.1 ml normal saline. At 90 s after injection the mice were killed and each had a rectal segment of 1 cm excised, weighed and the radioactivity of ^{86}Rb measured by counting in an autogamma counter for 5 min. The activity in the tail was also determined. Acrylic plastic flasks of 5 mm thickness were used to ensure sufficient absorption of high-energy electrons in order not to disturb the emission spectrum of the gamma rays by ^{86}Rb. The results were expressed as percentage of the injected dose:

$$\frac{A_r}{T - A_t} \times 100\% = \%\ \text{extracted}$$

where A_r = radioactivity in the rectal specimen, T = total injected radioactivity, and A_t = radioactivity in the tail.

If, through perivascular infiltration, the remaining radioactivity in the tail was more than 15% of the injected radioactive dose, these data were excluded.

Mean values and standard errors were calculated for each treatment group at various time-points. Statistical analyses were performed using Student's *t*-test.

RESULTS

The blood volume, as measured by ^{51}Cr-RBC, was significantly increased at Day 5 after both the low and high radiation dose of X rays alone (Fig. 1A). By Day 21, the values had returned to control levels. From Day 49 onwards, the blood volume decreased below control values, particularly after 22 Gy of X rays. When irradiation was given in combination with c-DDP, a significant increase at Day 5 was observed only after 22 Gy of X rays, whereas at later times there was a decrease below control values after both 16 and 22 Gy (Fig. 1B). The extent of this decrease was approximately the same as that after irradiation alone. It is noteworthy that after a radiation dose of 22 Gy, with or without c-DDP, animals could not be scored at Day 270, since they did not survive that long as was demonstrated previously (Dewit et al, 1987).

The largest functional changes were observed in the vascular permeability studies (Fig. 2). After X rays alone, there was a biphasic increase in vascular leakage (Fig. 2A). During the early phase (1–3 weeks after treatment) the permeability was increased by a factor of 1.8–2.3 after 16 and 22 Gy, respectively. The second wave of damage was progressive from 3–6 months onwards and occurred earlier after high-dose irradiation. By 6 months after this high X-ray dose the permeability was increased by a factor of 4 (Fig. 2A). Similar effects were observed after the combination treatment, although the biphasic pattern after 22 Gy was less clear than that after this radiation dose given alone (Fig. 2B). The increase in permeability was approximately by a factor of 2.5 at both 3 weeks and 6 months after c-DDP and 22 Gy of X rays.

The radiation-induced changes in relative perfusion as assessed by ^{86}Rb extraction were minor (data not shown). Only a slight, non-significant increase was observed within the first 3 weeks after irradiation. There was no trend in any changes at later times. Furthermore, no effect was seen when the drug was given in combination with X rays.

DISCUSSION

The present experiments have shown early functional changes in the microvasculature of the rectum, with the most

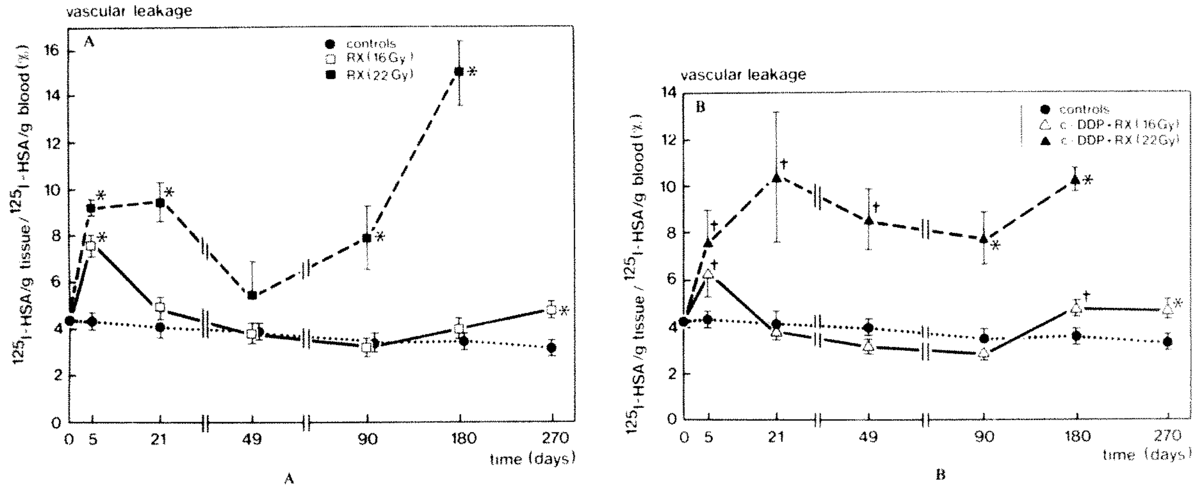


FIG. 2.

Vascular permeability in the rectum versus time after X rays (A) without and (B) with c-DDp (6 mg/kg). Values are the mean of six mice; error bars are ± 1 SEM. Marked data points were significantly different from control values: $*p < 0.002$, $+p < 0.02$.

prominent alteration being an increased vascular permeability within 5 to 21 days after irradiation. It is interesting to compare these data with our previously published histological alterations as a function of time after 16 or 22 Gy of X rays with or without c-DDP (Dewit et al, 1987). In those experiments, a persistent and dose-dependent dilatation of arterioles, capillaries and venules was observed from Day 21 onwards with a concomitant dose-dependent submucosal oedema.

Vaso-occlusive pathology was occasionally observed only after 49 days, and increased submucosal fibrosis became apparent not earlier than 3 months after treatment. This increased fibrosis was more marked after the high-dose irradiation and was most pronounced in the perivascular space.

By relating these histological observations with the present functional responses, it is conceivable that the increased vascular permeability was the overall effect of two different pathophysiological events. In the first few weeks, it was presumably the result of a generalised vasodilatation. This would also explain the transient increase in blood volume at Day 5 (Fig. 1). At later times, the increased vessel-wall leakage could also be due to endothelial-cell loss, as has been inferred from a number of experimental studies (Phillips, 1966; Hopewell & Young, 1978, Hirst et al, 1979). In response to this injury, clones of endothelial (Reinhold, 1974; Hopewell & Young, 1978, Hopewell et al, 1986) or subendothelial cells (Dimitrievich et al, 1977) can cause focal vaso-occlusive lesions. Such lesions would explain the reduced blood volume at later times. The vascular changes after irradiation did not seem to be modified by c-DDP.

Prolonged leakage of plasma constituents into the perivascular space has been suggested as the initiation of radiation-induced fibrosis (Rubin & Casarett, 1968). It is therefore possible that the early X-ray induced alterations in vascular permeability generate increased collagen formation in the submucosa of the rectum. This process gradually transforms the rectum into a rigid tube and, since it extends over the entire circumference, progressively narrows the rectal lumen. When the lumen becomes too narrow for fecal pellets to pass, an obstructive ileus develops which is fatal within a few days (Hubmann, 1981; Terry et al, 1983; Kiszel et al, 1984; Dewit et al, 1987).

In conclusion, the present data have shown severe early and persistent functional vascular changes after localised irradiation of the mouse rectum. It is suggested that these changes are causally related to the development of late radiation-induced rectal stenosis. The observed alterations after irradiation did not seem to be enhanced by c-DDP.

ACKNOWLEDGMENTS

The authors wish to thank Drs H. Bartelink, F. A. Stewart and A. C. Begg for stimulating discussions and Mrs A. Stuip for typing the manuscript. Dr B. Mijnheer is acknowledged for performing the dosimetry. This study was financially supported by het Koningin Wilhelmina Fonds (the Netherlands Cancer Foundation), grant NKI 84–1.

REFERENCES

BLACK, W. C., GOMEZ, L. S., YUHAS, J. M. & KLIGERMAN, M. M., 1980. Quantification of the late effects of X-irradiation on the large intestine. *Cancer*, *45*, 444–451.

BOHART, R. D., OGAWA, G., PRESTAYKO, A. W., CADIZ, M. & CROOKE, S. T., 1979. An observation on the stability of cis-dichlorodiammineplatinum (II): a caution regarding its administration. *Cancer Treatment Reports*, *63*, 2117–2119.

BREITER, N. & TROTT, K. R., 1986. The pathogenesis of the chronic radiation ulcer of the large bowel in rats. *British Journal of Cancer*, *53 (Suppl. VII)*, 29–30.

DEWIT, L., OUSSOREN, Y. & BARTELINK, H., 1987. Early and late damage in the mouse rectum after irradiation and cis-diamminedichloroplatinum (II). *Radiotherapy and Oncology*, *8*, 57–69.

DIMITRIEVICH, G. S., HAUSLADEN, S. L., KUCHNIR, F. T. & GRIEM, M. L., 1977. Radiation damage and subendothelial repair to rabbit ear chamber microvasculature. *Radiation Research*, *69*, 276–292.

GRAY, S. J. & FRANK, H., 1953. The simultaneous determination of red cell mass and plasma volume in man with radioactive sodium chromate and chromic chloride. *Journal of Clinical Investigations*, *32*, 1000–1004.

HIRST, D. G., DENEKAMP, J. & TRAVIS, E. L., 1979. The response of mesenteric blood vessels to irradiation. *Radiation Research, 77*, 259–275.

HOPEWELL, J. W. & YOUNG, C. M. A., 1978. Changes in the microcirculation of normal tissues after irradiation. *International Journal of Radiation Oncology, Biology, Physics, 4*, 53–58.

HOPEWELL, J. W., CAMPLING, D., CALVO, W., REINHOLD, H. S., WILKINSON, J. H. & YEUNG, T. K., 1986. Vascular irradiation damage: its cellular basis and likely consequences. *British Journal of Cancer, 53 (Suppl. VII)*, 181–191.

HUBMANN, F. H., 1981. Effect of X-irradiation on the rectum of the rat. *British Journal of Radiology, 54*, 250–254.

KISZEL, Z., SPIETHOFF, A. & TROTT, K. R., 1984. Large bowel stenosis in rats after fractionated local irradiation. *Radiotherapy and Oncology, 2*, 247–254.

PHILLIPS, T. L., 1966. An ultrastructural study of the development of radiation injury in the lung. *Radiology, 87*, 49–54.

REINHOLD, H. S., 1974. Structural changes in blood vessels. *Current Topics in Radiation Research Quarterly, 10*, 58–74.

RUBIN, P. & CASARETT, G. W., 1968. *Clinical Radiation Pathology*, Vol. I. (Saunders Company, Philadelphia), pp. 217–229.

SAPIRSTEIN, L., 1958. Regional blood flow by fractionated distribution of indicators. *American Journal of Physiology, 193*, 161–168.

TERRY, N. H. A., DENEKAMP, J. & MAUGHAN, P., 1983. RBE values for colo-rectal injury after caesium 137 gamma-ray and neutron irradiation. I. Single doses. *British Journal of Radiology, 56*, 257–265.

TROTT, K. R., 1984. Chronic damage after radiation therapy: challenge to radiation biology. *International Journal of Radiation Oncology, Biology, Physics, 10*, 907–913.

1987, *The British Journal of Radiology*, *60*, 1041–1042 OCTOBER 1987

Correspondence

(The Editors do not hold themselves responsible for opinions expressed by correspondents)

Accuracy and precision in the measurement of relaxation times from nuclear magnetic resonance images

THE EDITOR—SIR,

We refer to the paper by Johnson et al (1987) which describes a method based on the minimum number (three) of scan images for calculation. The authors state that "A multiple scan examination is impractical with patients because it can take several hours".

Previously published data in this journal (Jenkins et al, 1985; Hickey et al, 1986) and elsewhere have drawn attention to the need for a rigorous multiple-point approach to obtain precision and reproducibility of both T_1 and T_2 relaxation times in the realistic clinical situation, where the character of diseased tissues is unpredictable. Clinical imaging times for a 13-image data set, to include both T_1 and T_2 calculations in a region of interest from a single section on a 0.26 T Picker superconducting system, in our experience, have been approximately 50 min. Multiple-echo techniques now enable this time to be significantly reduced.

Relaxation times measured using the method suggested by Johnson et al for patient studies would, we believe, give limited tissue differentiation. There are several limitations in their approach, including the small number of data points, the use of pulse sequences with potentially different artefacts, short repetition times relative to T_1 values, spatial variation in the response across the image and the practice of obtaining the data from multislice images. The authors have not demonstrated the absence of crosstalk between slices, neither have they indicated what the slice profiles are, nor how they vary. The practice of collecting data from regions of interest, as suggested, produces results averaged over a large heterogeneous volume of tissue and would be expected to reduce discrimination (Prendergast et al, 1986). Furthermore, the apparent precision obtainable with two or three data points, employing selected pulse sequences, in a specified tissue, cannot be extrapolated to unknown pathology.

Yours, etc.,

J. P. R. JENKINS
D. S. HICKEY
I. ISHERWOOD
Departments of Diagnostic Radiology and Medical Biophysics
University of Manchester

(*Received April 1987*)

Reply

THE EDITOR—SIR,

Dr Jenkins and his colleagues do not believe that reliable relaxation times can be obtained with a limited number of data points (two points for each relaxation time) or from multislice sequences. They correctly list several (though not all) effects which might, in theory, give problems with the measurements. It was our awareness of these effects that led us to make the measurements of accuracy, noise, stability and uniformity presented in our paper. The results led us to conclude that, provided sufficient care is taken in setting up the sequences, these problems are not severe. We are not aware of any experimental evidence (rather than theoretical speculation) which contradicts this conclusion. Our phantom results are as follows: T_1 values show inaccuracy of about 1% up to values of 1400 ms; T_2 values are about 4%, low up to values of 300 ms. Slice-to-slice and within-slice non-uniformity are about 2%. Noise is about 1% (standard deviation) in T_1 values of about 500 ms, rising to 2% at 1 s; noise in T_2 is about 2% at 100 ms rising to 4% at 400 ms. It is quite possible for a badly set-up imager to give worse results than this. It is not obvious, however, how our approach could give results as good as these if it were inherently unsound.

Nor do our measurements on animals and patients support the conclusion that our two-point measurements give "limited tissue differentiation". We have shown (as have others: Lacomis et al, 1986) that the relaxation times of normal-appearing white matter (NAWM) are significantly elevated in multiple sclerosis (MS) patients relative to normal controls (Ormerod et al, 1987). The NAWM relaxation times in MS patients are also longer than those in patients with sarcoidosis and vasculitis (Miller et al, 1987a). We have also shown a connection between relaxation times and breakdown of the blood–brain barrier in MS lesions: lesions which enhance with gadolinium DTPA have a significantly larger T_1/T_2 ratio (Miller et al, 1987b). Our two-point measurements can be used to differentiate reliably between different forms of experimental cerebral oedema and gliosis (Barnes et al, 1986, 1987).

We should, perhaps, have expanded on our statement that a multiple-scan examination is impractical. The work in Manchester demonstrates that such examinations can be performed routinely. The extra data, however, are obtained at the cost of spatial resolution and can be acquired (at least for the T_1 measurements) only from *single* slices. Dr Jenkins et al do not specify the resolution and signal averaging of the images obtained in their 50 min protocol. Nor do they mention that repetition times generally have to be increased at higher field strengths. The equivalent of their 50 min protocol would take over an hour at 0.5 T. Our protocol gives high resolution (256 × 256 acquisition matrix, one signal average) relaxation-time images of eight slices in under 30 min. We therefore maintain that it is a far more practical protocol for routine clinical use.

The criticism of collecting data from regions of interest is entirely spurious. If one is interested in relaxation times *per se* it is the only practical way of making the measurements and Dr Jenkins himself used it in his measurements on vertebral discs (Jenkins et al, 1985). The texture analysis proposed by Prendergast et al (1986) is a very promising means of tissue discrimination but it is not a method of improving relaxation-time measurement.

We believe that our study represents the fullest investigation to date of the reliability of relaxation-time measurement *in vivo*. Our findings do not support the assertions of Dr Jenkins and his colleagues and we are not aware of any experimental or theoretical studies (including the papers they reference) which do.

Yours, etc.,
G. JOHNSON
I. E. C. ORMEROD
D. BARNES
P. S. TOFTS
D. MACMANUS

NMR Unit,
Institute of Neurology,
The National Hospital,
London WC1N 3BG

(*Received May 1987*)

REFERENCES

BARNES, D., MCDONALD, W. I., LANDON, D. N., JOHNSON, G., 1987. The characterisation of experimental gliosis by quantitative nuclear magnetic resonance imaging. Brain, in press.

BARNES, D., MCDONALD, W. I., TOFTS, P. S., JOHNSON, G., LANDON, D. N., 1986. Quantitative NMR imaging: Characterisation of experimental cerebral oedema. *Journal of Neurology, Neurosurgery and Psychiatry*, *49*, 1341–1347.

HICKEY, D. S., CHECKLEY, D. R., ASPDEN, R. M., NAUGHTON, A., JENKINS, J. P. R. & ISHERWOOD, I., 1986. A method for the clinical measurement of relaxation times in magnetic resonance imaging. *British Journal of Radiology*, *59*, 565–576.

JENKINS, J. P. R., HICKEY, D. S., ZHU, X. P., MACHIN, M. & ISHERWOOD, I., 1985. MR imaging of the intervertebral disc: a quantitative study. *British Journal of Radiology*, *58*, 705–709.

JOHNSON, G., ORMEROD, I. E. C., BARNES, D., TOFTS, P. S. & MACMANUS, D., 1987. Accuracy and precision in the measurement of relaxation times from nuclear magnetic resonance images. *British Journal of Radiology*, *60*, 143–153.

LACOMIS, D., OSBAKKEN, M., GROSS, G., 1986. Spin-lattice relaxation (T_1) times of cerebral white matter in multiple sclerosis. *Magnetic Resonance in Medicine*, *3*, 194–202.

MILLER, D. H., DU BOULAY, E. P. G. H., KENDALL, B. E., MOSELEY, I. F., JOHNSON, G., MCDONALD, W. I., 1987a. Differentiation of multiple sclerosis from other inflammatory multifocal central nervous system diseases: an MRI study. Submitted for presentation at Society of Magnetic Resonance in Medicine Annual Meeting.

MILLER, D. H., RUDGE, P., MACMANUS, D. G., JOHNSON, G., BARNES, D., MCDONALD, W. I., 1987b. Serial MRI studies with gadolinium-DTPA in acute relapsing multiple sclerosis. Submitted for presentation at Society of Magnetic Resonance in Medicine Annual Meeting.

ORMEROD, I. E. C., JOHNSON, G., MACMANUS, D., DU BOULAY, E. P. G. H., MCDONALD, W. I., 1987. Relaxation times of apparently normal cerebral white matter in multiple sclerosis. *Acta Radiologica*, in press.

PRENDERGAST, D. J., HICKEY, D. S., MACHIN, M., JENKINS, J. P. R. & ISHERWOOD, I., 1986. Texture analysis of multiple point relaxation time images. In *Proceedings of the Fifth Annual meeting of the Society of Magnetic Resonance in Medicine, Montreal* (Society of Magnetic Resonance in Medicine, Berkeley), Works in Progress, pp. 93–94.

Divergence of opinion over the linear-quadratic model

THE EDITOR—SIR,

In several recent papers, it has been suggested that the linear-quadratic (LQ) model may be of value for the solution of problems in clinical radiotherapy which involve changes in fractionation (Thames et al, 1983; Fowler, 1983, 1984; Dale, 1986a, b). I have been in correspondence with several radiobiologists and radiotherapists on this topic and it appears that there are quite sharp divergences of opinion. To initiate discussion, I would like to raise four questions.

(1) Is the time factor important?

Under what circumstances might the absence of a time factor in simple LQ theory mislead the clinician? Recent reviews make it clear that time is still a vital factor in fractionation theory. For instance, Fowler (1984) says "The method described above is easy to use; requires the conscious choice of an α/β ratio for specific tissues; and conscious choice of new time corrections." But in the same article there was a calculation which omitted time. In the most recent of his excellent series of papers, Dale (1986b) offers a graphical method to simplify the application of the LQ dose–effect relation to fractionated therapy. These graphs are based on simple LQ theory, omitting time, although there is a warning about proliferation. The need for a time factor was considered by Wheldon et al (1986).

(2) Is a tumour an early-responding tissue?

There is agreement with respect to the effect of dose per fraction on early and late normal-tissue reactions. In Fowler's words (1984) "It has become clear that a few large X-ray dose fractions cause worse late reactions than many small doses, when schedules yield equally acceptable early reactions". The difficulties arise when we ask whether a tumour responds as an early- or a late-reacting normal tissue. The important compilation of Williams et al (1985) is often quoted in this connection. They showed, granted certain assumptions, that tumours have relatively high α/β ratios, *i.e.* they resemble early-reacting normal tissues. To obtain their results, they only considered cases where reoxygenation and repopulation could almost certainly be eliminated, *i.e.* clamped or misonidazole-treated tumours and short overall times. This was a perfectly logical procedure, granted the assumptions which underlie the "Fe" plot of Douglas and Fowler (1976), *i.e.* the exclusion of complicating factors such as repopulation. However, a radiobiologist, or even a radiotherapist, might object to these data if they believe that reoxygenation and repopulation are significant factors in tumour response. Williams et al (1985) also confined their attention mostly to cases where the doses per fraction were relatively large, *i.e.* a situation where the LQ analysis may not be entirely reliable.

I would like to suggest two new terms which may help to clarify this issue. Let us call the α/β ratio obtained in the absence of complicating factors the *intrinsic* α/β ratio (α/β (i)), and the α/β ratio which includes repopulation, reoxygenation, etc. the *apparent* α/β ratio (α/β(a)). It will also be necessary to define α/β (i) further, to include the oxygen status of the tissue concerned. (Williams et al (1985), took fully oxic tissue as their baseline.) It may then be asked, which is the clinically relevant parameter, α/β (i) or α/β (a)?

If data are available for just two regimes for a given isoeffect, an apparent α/β ratio can be calculated. More detailed results may reveal that, in the presence of complicating factors, an Fe plot no longer gives a straight line (Suit et al, 1977). In this case the use of α/β (a) might not be justified. But if we do not have precise information about α/β (a), can we predict which regime will give a therapeutic advantage, if repopulation is a factor in radiotherapy?

(3) Are α/β ratios accurately known?

We should also ask how precise our knowledge of α/β ratios is, even in those cases where complicating factors can probably be excluded, *i.e.* in late-reacting tissues. What effect would an error of a factor of 2 in the α/β ratios have on predicted fractionation schemes?

(4) Does the LQ model have implications for hypofractionation?

Considerations based on the LQ model have suggested that hypofractionation would be disadvantageous in the clinic (Fowler, 1984) and some radiotherapists would agree (Cox, 1985). However, hypofractionation, in the form of relatively large fractions, has been practised successfully at St Thomas's for many years (Lloyd-Davies et al, 1971; Bates, 1975) for certain cases, notably post-mastectomy and prostatic cancer patients. Is there a contradiction here between radiobiological theory and clinical practice? For instance, do indolent prostatic tumours have relatively low intrinsic α/β ratios? How sensitive is the rate of tumour recurrence post-mastectomy to changes in X-ray dose?

The work of Singh (1978) has been quoted by radiobiologists and radiotherapists as an argument against the use of six large fractions. He very honestly reported a clinical disaster, when the dose per fraction was based on the TDF convention. Do we conclude that six fractions is a poor treatment schedule, or merely that the TDF system breaks down when applied to six fractions (Bates & Peters, 1975)?

Bates and Churchill-Davidson (1974) reported severe late reactions in cervix cases treated in HPO with 6 × 6 Gy in 18 days. Again, do we conclude that the use of six fractions is a mistake, or should we consider reducing the dose per fraction further? In his HPO trials, in the case of head and neck tumours, van den Brenk (1968) reduced the modal tissue dosage from 6 × 6 Gy to 6 × 5 Gy and claimed an equally good tumour response, whereas the normal-tissue reactions were much reduced. These are important issues which affect the planning of clinical trials with hypoxic-cell sensitisers. Henk and James (1978) advocated the use of hypofractionation in such trials, whereas Cox (1985) takes the opposite view.

In summary, there appears to be some difference of opinion between radiobiologists as to the application of the LQ model and in so far as this theory predicts that hypofractionation would be disadvantageous, radiotherapists are also included in this discussion. It is to be hoped that further submissions to the journal will elucidate the important problems raised by my four queries.

I would like to acknowledge the help of T. D. Bates, G. W. Barendsen, C. D. Collins, R. G. Dale, S. Dische, J. F. Fowler, A. H. W. Nias, L. J. Peters, H. D. Suit, H. D. Thames, K.-R. Trott, T. E. Wheldon and H. R. Withers. Any errors or misinterpretations are my own.

Yours, etc.,

Oliver C. A. Scott

Richard Dimbleby Department of Cancer Research,
United Medical and Dental Schools,
St. Thomas' Hospital,
London SE1 7EH

(Received February 1987 and in revised form May 1987)

REFERENCES

Bates, T. D., 1975. A prospective clinical trial of post-operative radiotherapy delivered in three fractions per week versus two fractions per week in breast carcinoma. *Clinical Radiology, 26,* 297–304.

Bates, T. D. & Churchill-Davidson, I., 1974. Hyperbaric oxygen combined with radiotherapy for carcinoma of the cervix. *British Journal of Radiology, 47,* 511–512.

Bates, T. D. & Peters, L. J., 1975. Dangers of the clinical use of the NSD formula for small fraction numbers. *British Journal of Radiology, 48,* 773.

Cox, J. D., 1985. Large-dose fractionation (hypofractionation). *Cancer, 55,* 2105–2111.

Dale, R. G., 1986a. The application of the linear-quadratic model to fractionated radiotherapy when there is incomplete normal tissue recovery between fractions, and possible implications for treatments involving multiple fractions per day. *British Journal of Radiology, 59,* 919–927.

——1986b. A graphical method to simplify the application of the linear-quadratic dose-effect equation to fractionated radiotherapy. *British Journal of Radiology, 59,* 1111–1115.

Douglas, B. G. & Fowler, J. F., 1976. The effect of multiple small doses of X-rays on skin reactions in the mouse and a basic interpretation. *Radiation Research, 66,* 401–426.

Fowler, J. F., 1983. La Ronde—radiation sciences and medical radiology. *Radiotherapy and Oncology, 1,* 1–22.

——1984. What next in fractionated radiotherapy? *British Journal of Cancer, 49, Suppl. VI,* 285–300.

Henk, J. M. & James, K. W., 1978. Comparative trial of large and small fractions in the radiotherapy of head and neck carcinoma. *Clinical Radiology, 29,* 611–616.

Lloyd-Davies, R. W., Vinnicombe, J. & Collins, C. D., 1971. The treatment of localized prostatic carcinoma. *Clinical Radiology, 32,* 230–234.

Singh, K., 1978. Two regimes with the same TDF but differing morbidity used in the treatment of Stage III carcinoma of the cervix. *British Journal of Radiology, 51,* 357–362.

Suit, H. D., Howes, A. E. & Hunter, N., 1977. Dependence of response of a C3H mammary carcinoma to fractionated irradiation on fractionation number and intertreatment interval. *Radiation Research, 72,* 440–454.

Thames, H. D., Peters, L. J., Withers, H. R. & Fletcher, G. H., 1983. Accelerated fractionation vs hyperfractionation: rationales for several treatments per day. *International Journal of Radiation Oncology, Biology, Physics, 9,* 127–138.

van den Brenk, H. A. S., 1968. Hyperbaric oxygen in radiation therapy. An investigation of dose-effect relationships in tumor response and tissue damage. *American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 102,* 8–26.

Wheldon, T. E., O'Donoghue, J. A. & Deehan, C., 1986. The linear-quadratic model and the α/β ratio: applications and limitations (abstract). *Proceedings of the European Society for Therapeutic Radiology and Oncology,* Baden-Baden, September 8–10, p. 188.

Williams, M. V., Denekamp, J. & Fowler, J. F., 1985. A review of α/β ratios for experimental tumours: implications for clinical studies of altered fractionation. *International Journal of Radiation Oncology, Biology, Physics, 11,* 87–96.

1987, *The British Journal of Radiology*, 60, 1044–1048

Proceedings of The British Institute of Radiology

Radionuclide investigations of the lung

Abstracts of papers presented at the above joint meeting with The Institute of Physical Sciences in Medicine Radionuclide Topic Group, held at Institute House, 36 Portland Place, London W1 4AT, on Wednesday, February 11, 1987

Chairmen: M. Buxton Thomas
P. S. Cosgriff
J. P. Lavender
P. F. Sharp

Lung vascular permeability in acute pancreatitis, by J. G. Hardy, C. S. Robertson and G. S. Basran
A double-radionuclide technique for measuring protein accumulation in the lung: experience in pulmonary oedema and adult respiratory distress syndrome, by D. Pearson, G. M. Rocker and D. J. Shale
How meaningful is abnormal lung permeability in symptom-free smokers? By R. A. Francis, R. G. Taylor, G. Woodman, D. Pavia, J. E. Agnew and S. W. Clarke
Lung-function measurements using positron emission tomography, by C. G. Rhodes, L. H. Brudin, S. O. Valind, P. E. Wollmer, T. Jones and J. M. B. Hughes
Quantitative krypton-81m studies using multiple single-breath and equilibrium images, by R. N. Arnot, R. J. Willetts, P. L. Horlock, M. E. Gwilliam and J. M. B. Hughes
Measurement of lung tissue mass, thoracic blood and interstitial volumes by transmission/emission scanning using technetium 99m, by P. D. Snashall, T. M. Bradley, P. Vernon, N. T. Cooke, C. Drinkwater, M. K. Gillet and B. A. Briggs
Validity of quantitative analysis of ventilation/perfusion lung scans, by B. E. Jones, P. Vernon, G. H. Burton, R. F. Jewkes and W. A. Seed
Multiple-view ventilation imaging using xenon 133, by C. J. Gibson, B. L. Diffey and L. E. Scott
A comparison of the quantification of ventilation images using aerosol and krypton 81m, by N. R. Williams, A. B. Mostafa, W. H. Thomson and L. K. Harding
Radioaerosol deposition measurements in inhalation therapy, by S. P. Newman
Effects of chronic airway obstruction on long-term retention of inhaled radioactive particles under simulated work conditions, by P. D. Diamond, D. Pavia, J. E. Agnew and S. W. Clarke
Aerosol ventilation imaging: the Lincoln way, by J. V. Skrypniuk
Ultra-fine aerosol particle ventilation imaging in patients with chronic airflow limitation, by J. E. Agnew, D. Pavia and S. W. Clarke
"Technegas": a new ventilatory agent, by C. McLaren

LUNG VASCULAR PERMEABILITY IN ACUTE PANCREATITIS

J. G. Hardy, C. S. Robertson and G. S. Basran

Queen's Medical Centre, Nottingham

Respiratory complications are associated with a high proportion of the deaths from acute pancreatitis. These acute lung injuries may be associated with increased vascular permeability and may result in patients developing the adult respiratory distress syndrome. Lung vascular permeability in patients with acute pancreatitis has been investigated and the results have been related to the clinical findings.

Lung permeability studies were undertaken on 16 patients with acute pancreatitis, confirmed by serum amylase levels of greater than 1000 IU/l: 10 patients had mild and six had severe acute pancreatitis complicated by clinically evident acute lung injury. The accumulation in the lungs of the plasma protein transferrin radiolabelled with $^{113}\text{In}^{\text{m}}$ was monitored over a 2 h period using a probe radiation detector, as described previously (Basran et al, 1985). Corrections were made for any changes in the circulating blood distribution by simultaneously monitoring $^{99}\text{Tc}^{\text{m}}$-labelled erythrocytes. The rate of plasma protein accumulation (PPA) in the lungs was expressed as an index. The 10 patients with mild acute pancreatitis all recovered and had normal PPA indices of $< 0.5 \times 10^{-3}\ \text{min}^{-1}$. All six patients with severe disease died. Five of these patients had elevated PPA indices.

Increased lung vascular permeability is not a feature of mild acute pancreatitis, but is found in severe disease and may be associated with secondary complications. Lung permeability studies may have a role in the evaluation of therapy for the management of the pulmonary complications of acute pancreatitis (Basran et al, 1986).

REFERENCES

Basran, G. S., Byrne, A. J. & Hardy, J. G., 1985. A non-invasive technique for monitoring lung vascular permeability in man. *Nuclear Medicine Communications, 6,* 3–10.

Basran, G. S., Byrne, A. J., Hardy, J. G. & Richardson, M. A., 1986. The effect of methylprednisolone on the pulmonary accumulation of transferrin in the adult respiratory distress syndrome. *European Journal of Respiratory Diseases, 68,* 336–341.

A DOUBLE-RADIONUCLIDE TECHNIQUE FOR MEASURING PROTEIN ACCUMULATION IN THE LUNG: EXPERIENCE IN PULMONARY OEDEMA AND ADULT RESPIRATORY DISTRESS SYNDROME

D. Pearson, G. M. Rocker and D. J. Shale

Department of Medical Physics, City Hospital and the Respiratory Medicine Unit, University of Nottingham, Hucknall Road, Nottingham

We have studied protein accumulation in patients with alveolar infiltrates of acute onset using a double-radionuclide method to label transferrin and red blood cells *in vivo* (Basran et al, 1985). An external sodium iodide scintillation detector was used to monitor activity in both lungs and the heart and a protein accumulation index (PAI) derived for each lung. Twenty patients who satisfied clinical criteria for adult respiratory distress syndrome (ARDS), 21 patients with non-ARDS pulmonary infiltrates and 11 normal volunteers were studied.

The mean PAI in the ARDS patients, taking only the higher value from two lungs, was 1.92 ± 1.52 and was significantly higher than the non-ARDS group (0.67 ± 0.76, $p < 0.01$) and the normal group (0.41 ± 0.44, $p < 0.01$). Fifteen of the 17 ARDS patients who died had a post-mortem examination, and histological examination of lung tissue was available in 13 patients, of whom 10 had diffuse alveolar damage consistent with ARDS and three had alternative diagnoses. The mean PAI in those patients with histologically proven ARDS was 2.69 ± 1.63, whilst those with an alternative diagnosis had a mean PAI of 0.37 ± 0.43. In order to establish that the measured PAI reflected a true biological effect, the significance of the PAI was determined using an analysis of variance on the null hypothesis that the PAI was zero. In patients with a diagnosis of ARDS, 90% of PAI values were significantly different from zero on the first occasion they were studied. This degree of significance was maintained throughout serial studies of ARDS-proven patients, whilst ARDS criteria held. Nine out of 21 non-ARDS patients (43%) and seven out of 11 normal volunteers (64%) had a significant PAI. Statistically significant and higher absolute PAI values occurred more frequently in ARDS. This easily performed, non-invasive double-radionuclide technique provides a reliable indication of protein leak in human ARDS.

REFERENCE

BASRAN, G. S., BYRNE, A. J. & HARDY, J. G., 1985. A non-invasive technique for monitoring lung vascular permeability in man. *Nuclear Medicine Communications*, 3, 3.

HOW MEANINGFUL IS ABNORMAL LUNG PERMEABILITY IN SYMPTOM-FREE SMOKERS?

R. A. Francis, R. G. Taylor, G. Woodman, D. Pavia, J. E. Agnew and S. W. Clarke

Departments of Thoracic Medicine and Medical Physics, Royal Free Hospital, London NW3 2QG

Young, symptom-free smokers demonstrate increased permeability of the lung to inhaled ^{99}Tc^{m}-DTPA. Smoking also tends to increase bronchial reactivity and in middle-aged smokers is associated with an accelerated rate of decline in spirometric lung function. We therefore investigated the relationship between small-airway function, bronchial reactivity (to histamine) and epithelial permeability (^{99}Tc^{m}-DTPA clearance from central and peripheral lung zones) in eight young smokers (mean age 27 years) and in 10 non-smokers (mean age 24 years).

Blood background corrected permeability half-times were significantly shorter ($p < 0.001$) in smokers than in non-smokers for both inner and outer lung zones. Nevertheless, neither inner- nor outer-zone half-times in smokers or non-smokers were significantly related to any index of small-airway function (based on flow–volume curves and nitrogen washout) or of bronchial reactivity to histamine. We conclude that whatever "permeability to DTPA" responds to (and its morphological basis in human smokers has yet to be established), it is too sensitive an index of airway integrity to indicate which smokers are particularly susceptible to the risks of long-term lung damage due to smoking.

Present address: Dr R. A. Francis, West Cumberland Hospital, Whitehaven, Cumbria, and Dr R. G. Taylor, Hull Royal Infirmary, Hull, Humberside.

LUNG-FUNCTION MEASUREMENTS USING POSITRON EMISSION TOMOGRAPHY

C. G. Rhodes, L. H. Brudin, S. O. Valind, P. E. Wollmer, T. Jones and J. M. B. Hughes

MRC Cyclotron Unit and Department of Medicine, Royal Postgraduate Medical School, Hammersmith Hospital, London W12 0HS

Regional measurements of tissue radionuclide concentration, made using positron emission tomography (PET), allow tracer models to be used in a quantitative manner to provide tomographic distributions of many structural and functional parameters, each derived in absolute units for the same well defined volume elements. Central to the development of such models is a clear definition of the various tracer distribution volumes. This is necessary to describe accurately the behaviour of the tracer and to relate tracer concentrations specified in a given model to those measured *in vivo*. Inevitably, this requires additional scan information. Because of the relatively long scan times required for many of the existing PET scanners, tracer models have centred around the use of steady-state techniques or uptake measurements in connection with biological systems with relatively slow turnover rates.

In this presentation, techniques to measure regional extravascular tissue mass and blood volume (g cm^{-3} and ml cm^{-3} thorax respectively), the ventilation-to-perfusion ratio (in absolute values) and metabolic measurements of carbohydrate utilisation (rate of ^{18}F-labelled 2-deoxy-D-glucose uptake, ml min^{-1} g^{-1}) are described. This ability to measure functional parameters in absolute units and in well defined volumes lends itself well to interparametric comparisons and thus to the investigation of lung pathophysiology.

QUANTITATIVE KRYPTON-81M STUDIES USING MULTIPLE SINGLE-BREATH AND EQUILIBRIUM IMAGES

R. N. Arnot, R. J. Willetts, P. L. Horlock, M. E. Gwilliam and J. M. B. Hughes

Department of Medical Physics and Medicine (Respiratory Division) and MRC Cyclotron Unit, Hammersmith Hospital and Royal Postgraduate Medical School, London

When ^{81}Kr^{m} of concentration c is breathed continuously, the regional ^{81}Kr^{m} equilibrium activity, A, is given by $A = \dot{V}c/(\dot{V}/V + \lambda)$. A is not proportional to ventilation $\dot{V}$ if the value of relative ventilation $\dot{V}/V$ is not negligible in comparison with the ^{81}Kr^{m} decay constant λ. A becomes increasingly dependent on regional volume, V, as $\dot{V}/V$ increases. To investigate this effect, a technique has been developed for imaging $\dot{V}$ with ^{81}Kr^{m} by summing single breaths of the gas; regional activity is then given by $A = \dot{V}c$. Washout of ^{81}Kr^{m} is also recorded for measurement of $\dot{V}/V$. Comparisons between the two types of image in several postures are presented. For example, in subjects lying on their sides, $\dot{V}/V$ in the lower lung was similar in value to λ and about three times the value in the upper lung. Then the lower-to-upper ratio of count density was found to be about 30% greater in single-breath images than in equilibrium images, owing to a deficit of counts in the equilibrium image of the lower lung. A method for measuring regional $\dot{V}/V$ using the two images is being investigated.

MEASUREMENT OF LUNG TISSUE MASS, THORACIC BLOOD AND INTERSTITIAL VOLUMES BY TRANSMISSION/EMISSION SCANNING USING TECHNETIUM 99M

P. D. Snashall, T. M. Bradley, P. Vernon, N. T. Cooke, C. Drinkwater, M. K. Gillett and B. A. Briggs

Department of Medicine and Nuclear Medicine, Charing Cross Hospital, Fulham Palace Road, London W6 8RF

Lung disease may alter the volume of vascular, interstitial and cellular lung compartments in a variety of ways and the measurement of compartment volumes may therefore be of value in diagnosis and monitoring of such diseases. We have attempted to measure transthoracic compartment volumes by a combination of transmission and emission scanning. We labelled red blood cells (RBC) with 111 MBq $^{99}\mathrm{Tc^m O_4}$ and 10 min later scanned the thorax for 2 min in the antero-posterior position with subjects seated, breathing quietly. To label the extracellular space we injected $^{99}\mathrm{Tc^m}$ DTPA intravenously and scanned the thorax 5 min later. In order to obtain a scan of $^{99}\mathrm{Tc^m}$ DTPA without blood, the previously stored blood image was subtracted from the composite image. Gamma-camera images were analysed using a computer program which defined lung boundaries on the transmission scan and found a strip of maximum transmission (five pixels in width) down each lung from apex to base. Transmission strips were transferred to the emission scans and used to correct emission counts for attenuation. $^{99}\mathrm{Tc^m}$ RBC and $^{99}\mathrm{Tc^m}$ DTPA water volumes per pixel were calculated and converted to an equivalent transthoracic thickness in each pixel. Plasma thickness was calculated from $^{99}\mathrm{Tc^m}$ RBC thickness and haematocrit, and this was subtracted from $^{99}\mathrm{Tc^m}$ DTPA thickness to obtain interstitial thickness. Transthoracic tissue thickness was partitioned into its chest-wall and lung compartments using a lateral chest radiograph.

TABLE I

	Thickness (cm)		
	Lung	Blood	Interstitial
Normal	3.4 (0.5)	2.0 (0.3)	0.85 (0.2)
Emphysema	2.0* (0.9)	1.3† (0.7)	1.0 NS (0.5)
Chronic interstitial pneumonitis	7.1† (3.5)	1.9 NS (0.6)	2.4† (1.1)

*$p = 0.005$; †$p = 0.05$; NS = no significant difference from normal group values.

We have applied this technique to normal subjects ($n = 8$) and patients with severe emphysema ($n = 5$) and chronic interstitial pneumonitis ($n = 7$). In the basal region of the right lung the mean (±SD) values given in Table I were obtained. The values seem highly plausible when compared with normal values obtained with other techniques and when related to the pathology of the condition studied.

VALIDITY OF QUANTITATIVE ANALYSIS OF VENTILATION/PERFUSION LUNG SCANS

B. E. Jones, P. Vernon, G. H. Burton, R. F. Jewkes and W. A. Seed

Departments of Medicine and Nuclear Medicine, Charing Cross Hospital, London

Automated quantitative analysis of ventilation/perfusion ($^{81}\mathrm{Kr^m}/^{99}\mathrm{Tc^m}$ MAA) lung scans has been applied to cases selected from among over 2000 scans performed in a diagnostic nuclear medicine department. From these cases over 100 have been selected with carefully documented pulmonary pathology (asthma, chronic obstructive airway disease or pulmonary embolism (PE)) and the results of the analysis compared with results of contemporary objective tests of lung function (blood gases, forced expiratory volume at 1 s, forced vital capacity and peak expiratory flow rate). In acute disease (asthma, PE) the degree of mismatch of ventilation and perfusion was shown to correlate well with the degree of hypoxaemia, and, in addition, in acute asthma the magnitude of the ventilation defect shown in the analysis correlated with the severity of airway obstruction. In chronic lung disease no such correlation was demonstrated: in general, the physiological tests showed better lung function than might be expected from the scan analysis. One hundred and twenty scans were analysed visually by experienced nuclear medicine staff and the abnormality scores compared with the values obtained in the automatic analysis. The results are shown and the possible usefulness of the technique in cases of mixed lung pathology discussed.

MULTIPLE-VIEW VENTILATION IMAGING USING XENON 133

C. J. Gibson, B. L. Diffey and L. E. Scott

Regional Medical Physics Department, Dryburn Hospital, Durham DH1 5TW

The role of pulmonary scintigraphy as a sensitive and non-invasive method for the diagnosis of pulmonary embolism (PE) is well documented. The diagnostic accuracy of detection of PE is significantly increased when both ventilation and perfusion images are available. We have developed a simple procedure for ventilation imaging which has the following properties. (a) Use of ^{133}Xe, which is widely available for a 24 h, 7 day emergency service. (b) provision of three inhalation views (postero-anterior, right posterior oblique and left posterior oblique), corresponding to the most useful perfusion images, with a high count density in each image. (c) Simple apparatus with no CO_2 absorber or significant dead space, and with direct discharge of waste ^{133}Xe to the outside air. (d) Radiation dose comparable with existing ventilation-scan protocols which require equilibration and washout of ^{133}Xe.

Analysis of 52 consecutive cases with at least one perfusion defect showed a significant increase ($p < 0.05$) in the number of matched defects seen when oblique-view ventilation images were available. A review of 500 patients studied using either the conventional or the revised procedure showed a significant decrease in the number of equivocal reports given ($p < 0.01$), with a corresponding increase in observer confidence.

A COMPARISON OF THE QUANTIFICATION OF VENTILATION IMAGES USING AEROSOL AND KRYPTON 81M

N. R. Williams, A. B. Mostafa, W. H. Thomson and L. K. Harding

Physics and Nuclear Medicine Department, Dudley Road Hospital, Birmingham

When krypton is not available, aerosol is satisfactory as a ventilation agent, particularly for patients with suspected pulmonary embolism who do not have chronic obstructive airway disease (COAD). However, quantification of ventilation distribution is sometimes required and it would be useful if the regional figures obtained were the same for both agents. We have assessed regional lung figures with both aerosol and krypton in 13 normal subjects and 18 patients with bronchial carcinoma and underlying COAD. Comparison of the aerosol and krypton (Kr) data showed greater aerosol accumulation in the left lung of the normal group (aerosol 48%, Kr 46%, $t = 5.1$, $p < 0.01$) and in the patient group with right-sided carcinoma (aerosol 69%, Kr 62%, $t = 3.2$, $p < 0.01$). In those patients with left-sided carcinoma there was no difference between the aerosol and krypton figures for the right lung. The normal group showed significantly more aerosol than krypton in the basal zone for both lungs (right lung: aerosol 61%, Kr 58%, $t = 2.2$, $p < 0.05$; left lung: aerosol 59%, Kr 55%, $t = 2.9$, $p < 0.02$), while in the patient group the basal increase was evident only in the left lung (aerosol 57%, Kr 50%, $t = 3.6$, $p < 0.01$). The difference in the whole-lung figures is in part due to the effect of the heart on the krypton images. The basal increase in aerosol activity is mainly due to differing clearance times for the upper and lower zones but the specific ventilation component of the krypton distribution is a contributory factor. Finally, evidence of a distinct band of basal activity in some patients suggests a further factor is involved at the diaphragmatic border of the lung.

RADIOAEROSOL DEPOSITION MEASUREMENTS IN INHALATION THERAPY

S. P. Newman

Department of Thoracic Medicine, Royal Free Hospital, Pond Street, London NW3 2QG

Therapeutic aerosols, of which bronchodilators are the best known, are administered by several types of inhalation device. While radionuclides are well established in the diagnosis of lung disorders, they also have a role to play in assessing and improving the efficiency of these devices. Both the amount of aerosol reaching the lungs and the distribution of aerosol among large airways, small airways and alveoli can be assessed by radiotracer methods, usually involving the radionuclide ^{99}Tc^{m}. Studies with pressurised metered dose inhalers have shown that deposition in the lungs is enhanced by slow breathing, breath holding and extension devices attached to the inhaler mouthpiece. In the case of air-driven "jet" nebulisers, aerosol deposition depends partly upon the breathing pattern, although the quantity of aerosol reaching the lungs is critically dependent on droplet size, which varies according to the type of nebuliser and the operating conditions; large droplets may not penetrate beyond the oropharynx. These findings may be used in conjunction with those of clinical studies to make recommendations about optimal choice of apparatus, its mode of operation and inhalation manoeuvre for efficient respiratory therapy. They may also yield information regarding the location of receptor sites for inhaled compounds.

EFFECTS OF CHRONIC AIRWAY OBSTRUCTION ON LONG-TERM RETENTION OF INHALED RADIOACTIVE PARTICLES UNDER SIMULATED WORK CONDITIONS

P. D. Diamond, D. Pavia, J. E. Agnew and S. W. Clarke

Departments of Thoracic Medicine and Medical Physics, Royal Free Hospital, London NW3 2QG

Estimates of aerosol particle deposition in industrial workers are generally based on theoretical and experimental data from normal subjects inhaling particles to an artificial, carefully regulated breathing pattern. Experimental data for subjects with chronic airflow limitation indicate much lower values for percentage long-term particle retention and, possibly, a different pattern of dependence on the breathing manoeuvre. Natural breathing patterns for subjects with chronic airflow limitation differ from those for normal subjects and in particular show a higher ratio of expiratory to inspiratory time.

Using mouth-breathing via a face-mask, we have compared 24 h retention (alveolar deposition, AD) of ^{99}Tc^{m}-labelled insoluble particles using an expiratory/inspiratory time ratio of 2.0 at two different breathing frequencies, representing light and heavy work conditions, and with two different particle sizes. Normal subjects comprised non-smokers and asymptomatic smokers (age < 50 years; mean 32 years), pack-years < 20 (mean 8.25) and forced expiratory volume at 1 s (FEV$_1$) $> 70\%$ predicted (mean 99%). Subjects with airflow limitation comprised smokers (age > 56 years, mean 66 years), with mean pack-years $= 56$ and predicted FEV$_1$ $\leqslant 50\%$ (mean 36%). In normal subjects the change from light to heavy breathing decreased mean AD by 25% ($n = 18$), range 14–46%, but in patients with chronic obstructive airway disease (COAD) the mean decrease was 6% ($n = 5$), range 3–9%. In normal subjects, change in particle size from 3 to 6 μm decreased AD by 12% ($n = 18$) but in COAD the decrease was 3% ($n = 7$). These results suggest that even for breathing patterns standardised to those typical for a person with COAD, systematic differences between subjects with and without airflow limitation exist for the pattern of response to different working conditions or different particulate exposure. These differences are relevant to establishing norms for working populations which include workers with airflow limitation.

AEROSOL VENTILATION IMAGING: THE LINCOLN WAY

J. V. Skrypniuk

Medical Physics Department, St George's Hospital, Lincoln

At St George's Hospital, Lincoln, ^{99}Tc^{m} DTPA aerosols have been used for the past 5 years for routine lung ventilation imaging in the diagnosis of pulmonary embolism. Several variations of the technique have been used with widely differing results. Two major problems have been encountered. Firstly deposition within the central airways resulted in poor peripheral penetration and secondly there was sometimes failure to accumulate the required activity within a reasonable breathing period.

When a commercially available nebuliser and separator system was evaluated it was found that two batches gave considerably different results. Batch 1 gave good-quality images on first use, with only two out of 50 patients showing significant central airway deposition. However re-use of equipment from this batch showed progressively lower lung-accumulation rates leading to long imaging times. The aerosol delivery rates from this batch were measured and were found to decrease during the course of nebulisation. This was associated with a decrease in mass median diameter of the aerosol particles and a build-up of trapped aerosol inside the separator device. The problem was overcome by increasing the radioactive concentration in the nebuliser by interposing a length of 22 mm anaesthetic tubing between the nebuliser and separator to reduce the deposition rate within the separator. Batch 2 gave poor-quality images with approximately 50% of patients showing central airway deposition. This problem was ameliorated by using separators in series, and finally overcome by "wetting" the separator with saline solution before loading the nebuliser.

A multiseparator system with a device for initial particle settle-out has been found to give consistently reliable results. The ability to recycle separators has resulted in substantial cost savings. There is clearly a requirement for tighter quality control by system manufacturers.

ULTRA-FINE AEROSOL PARTICLE VENTILATION IMAGING IN PATIENTS WITH CHRONIC AIRFLOW LIMITATION

J. E. Agnew, D. Pavia and S. W. Clarke

Departments of Medical Physics and Thoracic Medicine, Royal Free Hospital, London NW3 2QG

Ultra-fine aerosol particles (much less than 1 μm diameter) can be prepared from $^{99}Tc^m$ pertechnetate solution by a carefully controlled two-stage heating procedure. Particles of so small a size should be subject to negligible lung deposition by inertial impaction even when inhaled at fast flow rates. They should therefore give good visualisation of the lung periphery unaccompanied by the central airways "hot spots" frequently found when larger particles are inhaled by patients with airways obstruction. We have investigated the lung deposition of ultra-fine aerosol particles in six tests on patients with chronic airflow limitation (mean maximal expiratory mid-flow rate = 21% predicted, range 11–42%). The particles were obtained from prototype equipment intended for clinical ventilation imaging. All patients found the equipment easy to inhale from. Mean penetration index of the aerosol particles relative to $^{81}Kr^m$ gas was 0.98 (range 0.81–1.10); some localised patchiness of deposition was seen in two patients. Clearance of deposited $^{99}Tc^m$ from the lungs was slow, with a mean 24 h retention of 78% (range 57–89%).

We acknowledge the help of Amersham International plc and of Mr I. G. Tetley (Tetley Technologies) in collaborating with us in the assessment of prototype "Technegas" equipment.

"TECHNEGAS". A NEW VENTILATORY AGENT

C. McLaren

Department of Nuclear Medicine, Royal Canberra Hospital, Australia

As its name implies "Technegas" is a $^{99}Tc^m$ aggregate which has gas-like properties. Because of its ultra-fine particle size, and retention in the lung alveoli, Technegas represents a major breakthrough in ventilation lung scanning. Following administration of Technegas (one to three breaths), a full complement of planar views is possible, because there is no appreciable biological clearance from the lungs. Thus it also makes an ideal agent for ventilation tomography. All of the 20 tomographic studies performed so far have shown excellent peripheral detail, with no central airway deposition. Technegas has been used in our institution in over 250 patients with total compliance. In all cases diagnostic images were possible. In this paper examples of Technegas in planar and tomographic studies are presented. Finally, a computer subtraction method to determine objectively ventilation-perfusion mismatch from a tomography set is described.

BIR Bulletin

October 1987

RADIOLOGY '88

GLASGOW

23-25 May 1988

Take the high road to Radiology '88

The new Scottish Exhibition and Conference Centre is the setting for RADIOLOGY '88, the 46th Annual Congress of the British Institute of Radiology, to be held Monday–Wednesday 23–25 May 1988.

RADIOLOGY '88 will cover the breadth and depth of modern radiology, both diagnostic and therapeutic; it is open to members and non-members. A major element will be the presentation of proffered papers both orally and in poster form. This provides a wonderful opportunity for practitioners of all the disciplines which contribute to medical radiology to take part. Submissions can be on any subject but preference will be given to the following topics which will be linked to specific sessions:

diagnostic imaging
radiotherapy
radiation protection
magnetic resonance imaging
screening programmes
accident and emergency
ultrasound
efficacy
picture archiving and communication systems

But remember! The deadline for submission of proffered papers is **30 November 1987.**

Have you heard of MED **X** RAY? MED X RAY will be the biggest and best technical exhibition in the UK in 1988. It is a joint venture of the British Institute of Radiology and the College of Radiographers, whose annual conference follows RADIOLOGY '88, and it will last the six days of both events.

There will be time for enjoying yourself too. The Scottish Radiological Society, who are collaborating with the BIR on the programme, will host a pre-Congress reception on the Sunday evening and there are rumours of a golf competition. The City of Glasgow will host a lavish civic reception and concert in the magnificent City Chambers; and the BIR's annual dinner will follow on the Tuesday night with singers from Scottish Opera. For accompanying persons there will be the beauties of Loch Lomond and the very special Burrell Collection. You may even want to add on a highland holiday. Start planning now, so you can look forward to taking the high road to Scotland next May.

You should find a leaflet/call for papers with the September issue of the BJR. If not, please ring the BIR Conference Office on 01-580 4085 for your own copy.

The British Institute of Radiology, founded in 1897, is Britain's open forum for **everyone** concerned with medical radiology. Its members are drawn from medicine, science, radiography and industry. If you would like information about joining, our address is: The British Institute of Radiology, 36 Portland Place, London W1N 4AT. Tel. 01-580 4085.

Council and officers for 1987–88 session

The new session of the BIR starts on October 1, 1987. Details of Council and officers for this session are as follows.

President
G. Mountford MCAM, DIPM, MBIM, DCR

Past Presidents
R. J. Berry, QHP, MA, BSC, DPHIL, MD, FRCP, FRCR, FACR(HON)
P. N. T. Wells, DSC, FENG
I. Isherwood, MB, CHB, DMRD, FRCP, FRCR, FFRRCSI

Vice Presidents
B. S. Worthington, MRCS, LRCP, DMRD, FRCR
C. R. Hill, BA, PHD, DSC, MIEE, FINSTP
C. A. Joslin, MB, BS, FRCR, DMRT, MIERE, CENG

Honorary Treasurer
D. S. McIntosh, BSC, PHD, ARIC, MPS

Honorary Secretaries
Maureen Gowland, MB, CHB, FRCR, MRCP(HON)
M. Jean Harvey, TDCR, DMS

Honorary Editors
N. J. McNally, PHD, MSC, BSC
J. T. Patton, FRCP, FRCR

Council Members
Thelma Bates, MB, CHB, MRCR, LRCP, MCRA, FRCR
Pauline A. Blackbourn, DCRT, FETC
E. S. Broadbridge, DSR, MSCT
M. Fitzgerald, BSC, MSC, MINSTP
N. W. Garvie, MB, BCHIR, DMRD
J. W. Hopewell, BSC, PHD
A. N. L. Kay
R. J. Lewis, TENG
V. R. McCready, MSC, MRCP, FRCR
R. F. Mould, BSC, MSC, PHD, FINSTP, FIMA, FIS
F. Ann Paris, FCR, TE, DMU
P. N. Plowman, MA, MD, MRCP, FRCR

D. Rickards, LRCP, MRCS FFR(D)SA, FRCR
C. W. Robertson, BSC, CENG, FIEE
P. H. S. Smith, BA, DPHIL
I. Watt, MB, MRCP, FRCR
J. M. Wilkinson, MSC

With representatives of
The Wessex Branch
P. L. Cook, FRCR, DMRD, DOBSTRCOG

The North of England Branch
T Healey, MB, CHB, DRMD, FRCR, MINUCE

The Welsh Branch
G. M. Roberts, MD, MRCP, FRCR, DMRD

The South-Western Branch
P. J. Briers, BSC, MB, BS, MRCP, FRCR

Scientific programme details are on page B69 of the Bulletin.

Obituary

Dr J. W. D. Bull, CBE, MA, DMR (London), MD, FRCP, FRCS, FACR (Hon), FRACR (Hon)

The distinguished British radiologist, Dr James Bull, a former President of the Institute and leader of the profession, died on July 5, 1987 at the age of 76 years. He was known internationally as an architect of the subspecialty neuroradiology and helped, more than any other man, to train the first generation of professional neuroradiologists in the English-speaking world.

James William Douglas Bull was born in 1911, the son of a doctor and the nephew of a doctor who pioneered the clinical use of X rays. From Repton School he went to Gonville and Caius College, Cambridge, and enrolled in 1930 as a medical student at St George's Hospital, London. This apprenticeship began a 40-year association with the hospital, in which he served successively as a house physician, medical registrar, trainee radiologist, consultant and director of the X-ray department, and pioneer neuroradiologist. It was at St George's that he met one of the men destined to shape his career, Wylie McKissock, then a young neurosurgeon, who realised that modern neurosurgery required X-ray skills not yet available in England. McKissock convinced Bull and helped him, after he obtained his London DMR in 1938, to visit Stockholm as a Rockefeller Foundation travelling scholar. At the Serafimer Hospital he was introduced to the new radiological approach to intracranial diagnosis, utilising Erik Lysholm's techniques and the revolutionary X-ray apparatus designed by Georg Schönander. The outbreak of war interrupted Bull's studies and, after being commissioned as a major in the Royal Army Medical Corps, he was posted to the Far East and almost immediately captured. He spent the next 5 years in a Japanese prisoner-of-war camp—an experience he never spoke of, but was never entirely able to put behind him.

Repatriated after the war, Bull immediately returned to Stockholm. These were the seminal years for neurological X-ray examinations such as encephalography, myelography and cerebral angiography, and Bull was involved at the start. He returned to London in 1948, competent and enthusiastic to introduce the new techniques and to assist McKissock at St George's (Atkinson Morley's Hospital, Wimbledon). In that year he performed the first percutaneous carotid angiogram in Britain at the National Hospital, Queen Square, where he was appointed assistant to Hugh Davies, the radiologist. Davies himself was a pioneer user of X rays in neurological diagnosis, having spent the war in the neurosurgical unit of Sir Hugh Cairns at Oxford, and he welcomed the younger man. Davies was Bull's second benefactor, whose self-effacement and support enabled him soon to move on to the stage of world neuroradiology. In 1955, at the age of 44, he was elected President of the Fourth Symposium Neuroradiologicum in London.

Bull's post-war career was divided between Queen Square and St George's, and he made these two hospitals into powerhouses of neuroradiological activity. He installed Swedish X-ray apparatus, established protocols for performing each examination correctly, and publicised neuroradiology to his clinical colleagues in the hospitals and outside. His aggressive approach reaped high dividends in the young doctors attracted to his side by the chance to acquire unique skills. Soon they began crossing the Atlantic and arriving from the Antipodes, and their presence brought further rewards through their value, after appropriate training, as research workers and exportable neuroradiologists. For a quarter of a century, Bull remained the driving force behind this activity—in diagnosis, craft instruction, teaching and travelling. To all these tasks he brought an unbounded enthusiasm for anything remotely connected with radiology, drive and persistence which, if measured in terms of getting things done, must be described as ruthless, and a charm which could always brighten the day and sometimes helped to demolish the opposition.

Bull's success at keeping his departments properly equipped—a task just as depressing in the NHS of 25 years ago as today—was unquestionably his greatest achievement. As each new discovery became known, he always managed quickly to acquire the apparatus—sometimes in unconventional ways. Thereafter, the sequence of events was the same: the validity of the new technique was immediately tested clinically, then a diagnostic protocol was laid down, and soon the apparatus was harnessed to routine use. In this way, Bull successfully popularised precision skull radiography, oil myelography, positive contrast ventriculography, radionuclide brain imaging, ultrasonography and CT brain scanning. His published papers (see below) reflect the chronology of this activity: his bibliography is a history of neuroradiology. His curiosity never waned: a few months ago he wrote, "I am reading up, and trying to understand the scientific basis of magnetic resonance, which seems to be replacing CAT of the brain".

James Bull was a born leader and he looked every inch the part. Tall and invariably well dressed, his commanding appearance and strong voice helped to place him naturally *primus inter pares*. Abroad, he will be remembered as a truly great ambassador of British medicine: formal and polite, speaking the Queen's English and talking commonsense—in short, matching up to what foreigners expect of an Englishman. At different times he occupied the three traditional presidencies of British radiology: Institute of Radiology, Section of Radiology of the Royal Society of Medicine, and the (then) Faculty of Radiologists. He was founder President of the British Society of Neuroradiologists, and subsequently served as a distinguished President of the European Society of Neuroradiology. He delivered most of the prestigious eponymous lectures in the radiological calendar, and countless bodies elected him to honorary membership. Honours bestowed upon him, which are unique gifts for a British radiologist, included honorary fellowship of the Royal College of Surgeons, honorary fellowship of the Royal Society of Medicine, deanship of the Institute of Neurology, Queen Square, and honorary membership of the Radiological Society of North America.

The death in 1978 of his wife Edith, who supported him loyally, was a severe blow. He is survived by a son and a daughter.

E. H. Burrows

BIBLIOGRAPHY

Books and chapters
1951:
(Chapter) Radiography of the Head. In *H.C.H. X-Ray Interpretation*. London.
(Chapter) Neuroradiology. In *Feiling's Modern Trends in Neurology*. (Butterworths, London)
1961:
(Chapter) Radiology of Strokes. In *Scientific Aspects of Neurology*. Ed. by H. Garland (Livingstone, Edinburgh).
1962:
(Book with W. McKissock). *An Atlas of Positive Contrast Myelography*. (Grune and Stratton, New York).
1967:
(Chapter, with R. Blend). The radiological investigation of migraine. In *Background to Migraine*. Ed. by R. Smith (Heinemann, London).
1969:
(Chapter, with I. M. S. Wilkinson, G. H. du Boulay et al). The heterogeneity of blood flow throughout the normal cerebral hemisphere. In *Cerebral Blood Flow*. Ed. by M. Brock et al (Springer, Berlin).
1975:
(Chapter, with G. D. Hungerford & J. Gawler). Computed assisted tomography and angiography in the diagnosis of cerebral tumours. The changing role of angiography. In *Advances in Cerebral Angiography*. Ed. by G. Salamon (Springer, Berlin).

Original Papers
1940:
Radiological diagnosis of chronic subdural haematoma. *Proceedings of the Royal Society of Medicine, 33,* 203–224.
Diagnosis and treatment of intracranial tumours. *Practitioner, 144,* 379–387.
1946:
Paget's disease of the skull with platybasia. *Proceedings of the Royal Society of Medicine, 40,* 85–87.
1948:
Discussion on rupture of intravertebral disc in the cervical region. *Proceedings of the Royal Society of Medicine, 41,* 509–516.
1949:
The diagnosis of chronic subdural haematoma in children and adolescents. *British Journal of Radiology, 22,* 68–80.
(with D. Sutton). The diagnosis of paraphysial cysts. *Brain, 72,* 487–516.
(jointly). A review of cerebral angiography. *Brain, 72,* 487–516.
1950:
Positive contrast ventriculography. *Acta Radiologica, 34,* 253–268.
Cerebral angiography. *Postgraduate Medical Journal, 26,* 157–165.
1951:
(with J. P. Martin, P. C. P. Clarke et al). Discussion on less common cerebrovascular diseases. *Proceedings of the Royal Society of Medicine, 44,* 845–858.
1953:
The radiological diagnosis of intracranial tumours in children. *The Journal of the Faculty of Radiologists, 4,* 149–170.
(with G. Jefferson, J. H. Patterson et al). The radiological differential diagnosis of lesions of the posterior fossa. *Proceedings of the Royal Society of Medicine, 46,* 719–738.
Spinal meningiomas and neurofibromas. *Acta Radiologica, 40,* 283–300.
1955:
(with W. L. B. Nixon and R. T. C. Pratt). Radiological criteria and familial occurrence of primary basilar impression. *Brain, 78,* 229–247.
1956:
The normal variations of the position of the optic recess of third ventricle. *Acta Radiologica, 46,* 72–80.
1957:
(with E. L. Spatz). Vertebral arteriography in the study of subarachnoid hemorrhage. *Journal of Neurosurgery, 14,* 543–547.
(with R. L. Rovit). The radiographic localization of intracranial gliomata. *The Journal of the Faculty of Radiologists, 8,* 147.
1958:
Radiological investigation in cases of cerebrovascular disease. *British Medical Journal, i,* 795–797.
(with R. H. Rischbieth). The significance of enlargement of the superior orbital fissure. *British Journal of Radiology, 31,* 125–135.
(with M. M. Schechter and P. Carey). Two new encepholographic signs of pressure hydrocephalus. *British Journal of Radiology, 31,* 317–325.
1959:
(with W. L. B. Nixon, R. T. C Pratt and P. K. Robinson). Paget's disease of the skull and secondary basilar impression. *Brain, 82,* 10–22.
(with L. V. Perrett). Some aspects of subarachnoid haemorrhage. Symposium. III. The accuracy of radiology in demonstrating ruptured intracranial aneurysms. *British Journal of Radiology, 32,* 85–92.
1960:
Carotid insufficiency. *Transactions of the Ophthalmological Society of the United Kingdom, 80,* 267–280.
(with J. Marshall and D. A. Shaw). Cerebral angiography in the diagnosis of the acute stroke. *Lancet, i,* 562–565.
(with R. S. Couch, D. Joyce et al). Observer variation in cerebral angiography: an assessment of the value of minor angiographic changes in the radiological diagnosis of cerebrovascular disease. *British Journal of Radiology, 33,* 165–170.
1961:
The volume of the cerebral ventricles. *Neurology (Minneap.), 11,* 1–9.
History of neuroradiology. *British Journal of Radiology, 34,* 69–84.
(with H. Metz, R. M. Murray-Leslie, R. G. Bannister and J. Marshall). Kinking of the internal carotid artery. *Lancet, i,* 424–426.
Use and limitations of angiography in the diagnosis of vascular lesions of the brain. *Neurology (Minneap.), 11,* 80–85.

1962:

A short history of intracranial aneurysms. *The London Clinic Medical Journal, 3,* 47–60.

Contribution of radiology to the study of intracranial aneurysms. *British Medical Journal, ii,* 1701–1708.

(with H. Schunk). The significance of displacement of the cavernous portion of the internal carotid artery. *British Journal of Radiology, 35,* 801–814.

1963:

Difficulty in differentiating between fourth ventricle and brain stem masses. *Acta Radiologica Diagnosis, 1,* 814–820.

Neuroradiologica. *Revista Española de Oto-neuro-oftalmologica y Neurocirugia, 22,* 182–187.

1964:

Experiences in the localization of intracranial tumours with 203 Hg. *Proceedings of the Royal Society of Medicine, 57,* 1049.

(with J. Marryat). An apparatus providing combined radiography and gamma scan. *British Journal of Radiology, 37,* 711–713.

1965:

(with J. Marryat). Isotope encephalography: experience with 100 cases. *British Medical Journal, i,* 475–480.

(with J. H. Scatliff). The radiological manifestations of suprasellar metastatic disease. *Clinical Radiology, 16,* 66–70.

Localization of cerebral lesions by radioactive isotopes and ultrasound. *Proceedings of the Royal Society of Medicine, 58,* 1051–1053.

1966:

(with J. Howieson). Radiologic detection of astrocytoma involving the corpus callosum. *American Journal of Roentgenology, 98,* 575–578.

Topographical criteria for pathological diagnosis of intracranial masses by means of gamma encephalography. *Acta Radiologica Diagnosis, 5,* 754–759.

(with J. H. Scatliff and M. R. Crompton). Post mortem brain tumor angiography. *Acta Radiologica Diagnosis, 5,* 476–487.

1967:

(with D. F. Reese). Positive contrast demonstration of normal internal acoustic meatus, Meckel's cave, and jugular foramen. *American Journal of Roentgenology, 100,* 50–55.

The corpus callosum. *Clinical Radiology, 18,* 2–18.

L'applicazione clinica degli isotopi in neurologia. *Riforma Medica, 81,* 281.

Brain scanning. *Modern Medicine of Australia, 10,* 15.

1968:

Electroencephalography in Britain. *Lancet, ii,* 1240–1241.

Radioisotopes and radiographers. *Radiography, 34,* 154–155.

(with R. Hunter and W. Blackwood). Three cases of frontal meningiomas presenting psychiatrically. *British Medical Journal, iii,* 9–16.

Radiation dose in isotope encephalography. *Lancet, ii,* 871.

(with K. J. Zilkha). Rationalising requests for x-ray films in neurology. *British Medical Journal, iv,* 569–560.

1969:

Massive aneurysms at the base of the brain. *Brain, 92,* 535–570.

Medical staffing in the N.H.S. *Lancet, ii,* 540.

(with T. El Gammal and M. Popham). A possible genetic factor in cervical spondylosis. *British Journal of Radiology, 42,* 9–16.

The radiological investigation of a cerebral tumour suspect. *Journal of the Royal Naval Medical Service, 55,* 35–42.

The indications, contra-indications and possible dangers of positive contrast ventriculography. *Journal Belge de Radiologie, 50,* 117–120.

(with I. M. Wilkinson and G. H. du Boulay). Regional blood flow in the normal cerebral hemisphere. *Journal of Neurology, Neurosurgery and Psychiatry, 32,* 367–378.

(with A. J. Porter). Some aspects of the natural history of cerebral arteriovenous malformation. *British Journal of Radiology, 42,* 667–675.

Tentorium cerebelli. *Proceedings of the Royal Society of Medicine, 62,* 1301–1310.

1970:

(with J. E. Rees and G. H. du Boulay et al). Regional cerebral blood flow in transient ischaemic attacks. *Lancet, ii,* 1210–1213.

(with M. G. Popham and E. W. Emery). Interpretation of brain scans by computer analysis. *British Journal of Radiology, 43,* 835–847.

(with P. Kozlowski). The angiographic pattern of the petrosal veins in the normal and pathological. *Neuroradiology, 1,* 20–26.

The place of radiodiagnosis in medical education methods: methods. *Proceedings of the Royal Society of Medicine, 63,* 835–837.

The history of neuroradiology. *Proceedings of the Royal Society of Medicine, 63,* 637–643.

1971:

(with J. E. Rees, G. H. du Boulay et al). The comparative analysis of isotope clearance curves in normal and ischaemic brain. *Stroke, 2,* 444–451.

(with M. Gado). The carotid angiogram in suprasellar masses. *Neuroradiology, 2,* 136–153.

Myelography. *Neuroradiology, 2,* 1–2.

1972:

(with A. J. Campbell). Craniopharyngioma in a predominantly adult population. A radiologic review., *Journal of the Canadian Association of Radiologists, 23,* 182–191.

Neurology's debt to Becquerel. *British Journal of Radiology, 45,* 881–890.

1973:

(with R. H. Ackerman, E. Zilkha et al). The relationship of the carbon dioxide reactivity of cerebral vessels to blood pressure and mean testing blood flow. *Neurology (Minneap.), 23,* 21–26.

(with S. G. Rosenbaum, L. D. Iliff et al). Arterial peaks in regional cerebral blood flow 133 Xenon clearance curves. *Stroke, 4,* 73–79.

(with E. Wong, G. H. du Boulay et al). Regional cerebral blood flow in completed strokes and transient ischemic attacks. *Neurology (Minneap.), 23,* 949–952.

Technique of oil myelography. *British Medical Journal, 88,* 280–282.

1974:

(with J. Gawler, G. H. du Boulay et al). Computer-assisted tomography (EMI scanner). Its place in investigation of suspected intracranial tumours. *Lancet, ii,* 419–423.

(with L. Iliff, E. Zilkha et al). Effect of changes in cerebral blood flow on proportions of high and low flow tissue in the brain. *Journal of Neurology, Neurosurgery and Psychiatry, 37,* 631–635.

What is diagnostic radiology's place in medicine? *British Medical Journal, iii,* 394–400.

(with J. Gawler, M. D. Sanders et al). Computer assisted tomography in orbital disease. *British Journal of Ophthalmology, 58,* 571–587.

1975:

The nervous system's blood vessels from Galen to Rontgen and after. *Proceedings of the Royal Society of Medicine, 68,* 695–702.

(with V. L. McAllister and B. E. Kendall). Symptomatic vertebral haemangiomas. *Brain, 98,* 71–80.

1976:

(with J. Gawler, G. H. du Boulay et al). Computerized tomography (the EMI

scanner): a comparison with pneumoencephalography. *Journal of Neurology, Neurosurgery and Psychiatry, 39,* 203–211.
The future of computerised axial tomography. *Journal de Neuroradiologie (Paris), 3,* 335–338.
Medical and legal aspects of the increasing demand for diagnostic radiology. *Proceedings of the Royal Society of Medicine, 69,* 757–758.
(with J. Gawler, G. H. du Boulay et al). A comparison of computer assisted tomography (EMI scanner) with conventional neuroradiologic methods in the investigation of patients clinically suspected of intracranial tumor. *Journal of the Canadian Association of Radiologists, 27,* 157–169.
(with G. H. du Boulay, J. Marshall and J. Gawler). First results with an EMI scanner. *Acta Radiologica Supplementum, 347,* 495–498.

BIR North of England Branch: 1987 Spring Meeting

The 112th Meeting of the North of England Branch of the BIR was held at Barnsley District General Hospital, on Saturday, April 11, 1987, when the following papers were presented.

Imaging blood movement within the thorax using applied potential tomography

B. Brown
Weston Park Hospital, Sheffield

Applied potential tomography is a new technique which enables images of tissue electrical resistivity to be produced. It involves attaching an array of 16 electrodes around the body and the measurement of potential when small currents are passed at 50 kHz. The technique offers rapid data collection, a high sensitivity to resistivity changes at low cost, and no significant hazard to the patient. However, the spatial resolution is poor and the system is most unlikely to compete with other tomographic imaging modalities in giving anatomical detail. It should be seen as a method of measuring physiological function.

A five-year research programme in Sheffield has produced the present equipment which can collect data at 24 frames per s and reconstruct the images in approximately 10 s. By using an electrically resistive or conductive meal as a "contrast medium" it is possible to measure gastric emptying and this has been extensively validated against the use of gamma camera and a labelled meal. By using a ring of electrodes around the thorax and comparing lung inspiration with expiration, an image of lung ventilation can be produced. The spatial resolution is only approximately 2 cm but the two lungs are well resolved and regional changes in ventilation can be seen. There are good correlations with alternative but invasive methods of measuring lung ventilation.

Our most recent work enables the movement of blood during the cardiac cycle to be imaged. Blood has a low resistivity (1.6 Ωm) and hence on systole, the lungs fall in resistivity in proportion to stroke volume. The current images show the left and right ventricles and pulmonary artery dilatation.

Work is in progress to compare lung perfusion and ventilation data with the results of gamma camera ventilation perfusion.

What the GP expects from the X-ray department

J. Foster
Barnsley

Following a survey of GP colleagues, it was quite clear that most general practitioners were satisfied with the level of service provided by X-ray departments. The only criticisms are those of delayed or inadequate communication but it is quite clear that the barriers that have grown up are those of omission not intent.

Nuclear medicine and ultrasound thyroid imaging in Barnsley

J. Unsworth
Barnsley District General Hospital

Nuclear medicine imaging of the thyroid in Barnsley is carried out, as in most centres, with ^{99}Tc^{m} pertechnetate. ^{99}Tc^{m} pertechnetate is inexpensive and in the great majority of cases gives a satisfactory scan. Only rarely are ^{123}I iodide scans, which are free of background and salivary gland activity, necessary.

Thyroid ultrasound imaging was introduced in Barnsley 3 years ago and all radionuclide thyroid scans are now followed by an ultrasound examination, carried out with a 5 MHz mechanical sector scanner using a stand-off medium on the neck. A difficult problem of thyroid imaging is that of the "cold" nodule on the radionuclide scan. Reportedly, 20% of such nodules are cystic, 60% are benign solid nodules, and 20% are malignant. Ultrasound readily shows whether the nodule is cystic but cannot reliably indicate whether or not a solid nodule is malignant.

A technique has been described for carrying out a radionuclide perfusion study of the thyroid for the assessment of cold nodules. It is reported that benign nodules show vascularity equal to, or less than, normal thyroid tissue, while malignant nodules are hypervascular. The degree of activity administered in that report (370 MBq) is much higher than the maximum approved for thyroid imaging in this country. The technique had been adapted in Barnsley for use with an acceptable level of activity and useful perfusion studies can be obtained. This is illustrated with two recent examples.

It is concluded that nuclear medicine and ultrasound imaging of the thyroid should be carried out as a combined investigation and the scans reported together. Additionally, a perfusion study can readily be incorporated into the protocol of the radionuclide study which can give useful additional information.

"There must have been more to it than that"—two interesting cases

H. H. Pilling
Former South Yorkshire Coroner

Essentially this was a resumé of two cases for which, at first sight, surgical error appeared to have been the cause of death, but in which further enquiry brought to light a more probable natural cause.

The first of these concerned a woman who underwent a right nephrectomy for xanthogranulomatous pyelonephritis. She subsequently developed peritonitis which was attributed to an accidental perforation of the ascending colon by the diathermy needle at the time of the nephrectomy. After the inquest it was pointed out to the coroner who had returned an open verdict that fistula formation between the renal pelvis and the ascending colon is a recognised feature of this relatively rare condition in a few cases.

The second case was of a 13-year-old boy who died of pulmonary haemorrhage after tonsillectomy. At first he was thought to have inhaled the blood from post-operative haemorrhage, but this was show to have been impossible. The haemorrhage was thought more likely to have resulted from malignant hyperpyrexia.

Hip replacement in Still's disease

C. Ruddlesdin
Barnsley District General Hospital

No summary provided.

Radiological changes of opportunist mycobacterial infections seen in Barnsley

O. T. Tang
Barnsley District General Hospital

Until recently, routine identification of opportunist mycobacteria was not generally available. Clinical experience in such infections was consequently rather limited, and many were mistaken for resistant cases of tuberculosis. Some investigators had apparently identified radiological features of opportunist mycobacterial infections, thought to be sufficiently different from tuberculosis, as to be of diagnostic value. With increasing clinical experience arising from greater accessibility to laboratory facilities for identifying opportunist mycobacteria, it is now generally accepted that there is no major difference in the radiological appearance between pulmonary infections caused by *Mycobacterium tuberculosis* and those caused by opportunist mycobacteria.

Over a period of 6 years, between 1981 and 1986, there were 111 notifications of mycobacterial disease in Barnsley. Of these, 10 were due to opportunist mycobacteria. Two of these were gland infections in children caused by the *avium-intracellulare* group and eight were pulmonary diseases, of which six were caused by *M. kansasii* and two by *M. malmoense*. Three patients had pre-existing pulmonary diseases (two cases of certified pneumoconiosis and one case of bronchogenic carcinoma). Opportunist mycobacteria were thought to be present in these three patients as a result of colonisation rather than infection. The remaining seven patients exhibited a range of radiological features which did not differ in any major way from those seen in tuberculosis.

BIR Welsh Branch: 1987 Summer Meeting

The summer meeting of the Welsh Branch of the BIR was held at Bronglais General Hospital, Aberystwyth, on June 13, 1987, and was organised by Dr Hywel I. Davies. Professor R. J. Berry, the President of the BIR, was the guest at the annual dinner on June 12. Dr G. J. Griffiths was elected Secretary. The Scientific meeting was chaired by Dr G. M. Roberts who thanked the outgoing Chairman, Dr Rosemary Anderson, for her services to the Branch during the last 4 years. Abstracts of the lectures are given below. The 1987 autumn meeting will be held in Cardiff in November.

Current concepts in the diagnosis and treatment of biliary obstruction

R. B. Pickford
Nevill Hall Hospital, Abergavenny

The accurate diagnosis of biliary obstruction is beset with technical and practical difficulties. Computed tomography (CT) scanning, where available, is the most accurate method, including its use in the identification of ductal calculi. This is of particular value when the ducts are not dilated or are only slightly so. Ultrasound is the main investigative tool, and its value was assessed in 91 patients whose bile ducts were explored during the course of cholecystectomy. No correct positive diagnosis of ductal calculi was made in ducts of less than 9 mm (measured on ultrasound). Accuracy in diagnosis of biliary calculi is significantly improved utilising the erect position and a water-filled stomach.

Ultrasound-guided percutaneous transhepatic cholangiography (PTC) and biliary drainage via the left hepatic duct is a relatively simple technique, with a higher guarantee of success and safety than the orthodox radiological method. This method can be extended to performing percutaneous cholecystostomy for either diagnostic or therapeutic purposes.

There are a wide variety of ways of treating different forms of bilary obstruction and these depend on local expertise. Safety cannot be guaranteed with any method, but these recent innovations represent a significant advance over surgery. The Burhenne technique for removing retained calculi, and the use of dissolution agents such as MTBE (methyl-tert-butyl-ether) via percutaneous catheter in the gallbladder or ducts, do not require the specialist expertise of the interventional endoscopists. However, techniques such as radioactive iridium wire implant in the treatment of hilar cholangiocarcinoma need to be carried out at a regional centre.

Interventional radiology in the upper urinary tract

W. J. Norman (guest)
Royal Shrewsbury Hospital

Percutaneous puncture and catheterisation of the upper urinary tract permits a range of diagnostic and therapeutic procedures. Correct planning of the track into the collecting system is based on anatomical considerations and may be crucial to the success of the procedure.

Percutaneous nephrostomy is

indicated when obstructive uropathy becomes complicated by infection or renal failure. In the presence of infection the initial procedure should be confined to drainage, with diagnostic studies reserved until the infection has subsided.

The insertion of a ureteric stent may be carried out either as a radiological procedure or as a urological procedure according to the individual problem. Recent refinements in stent design have facilitated stent placement via the antegrade approach, though difficulties are frequently encountered with lower ureteric strictures. A combined antegrade and retrograde approach may be successful when other methods have failed. Where ureteric stent placement proves impossible, a Foley catheter introduced percutaneously into the renal pelvis provides acceptable longer-term drainage. The importance of careful patient selection and planning of the subsequent management of patients with malignant ureteric structures is emphasised.

The great majority of renal and ureteric calculi can be dealt with by percutaneous techniques, provided that the appropriate equipment and instruments are available. Most interventional procedures are time consuming and the provision of a service may present logistical problems in a district general hospital, particularly when screening-room time is limited.

Experience of percutaneous drainage of intra-abdominal abscesses

R. A. Byrne, C. A. McConnell and C. H. Wright
Glan Clwyd Hospital, Rhyl

The technical feasibility and clinical efficacy of percutaneous abscess drainage is now well established, and the results of a number of large series indicate a better outcome overall for percutaneous drainage, with lower rate of morbidity and mortality and fewer complications than have been reported with surgical drainage. An average success rate of greater than 80% has been demonstrated in four large series and only eight mortalities reported in an entire group of over 400 patients. These results compare favourably with surgical drainage, and there are a significant number of cases where percutaneous drainage improves the patient's clinical status so that they are better candidates for subsequent elective surgery.

The diagnosis of intra-abdominal abscess may be difficult. With both ultrasound and CT the appearances of haematoma, tumour and abscess may overlap. It may be necessary to perform a skinny needle aspiration to establish the diagnosis. Of 27 abscesses drained in a 3-year period, 11 were post-surgical complications, and 16 presented *de novo*. Of these 16 abscesses, 14 had a demonstrable underlying cause. The drainage procedure was performed with fluoroscopic guidance, with a portable real-time ultrasound scanner for initial localisation. The majority of cases had a pigtail drain inserted, sump and aspiration drainage being used occasionally. The contra-indications and complications of percutaneous drainage were briefly reviewed. Where a cavity continued to drain after a few days it was advisable to re-opacify the cavity with contrast to exclude the possibility of a fistulous connection. Those patients undergoing repeat drainage were found to have such a connection in every case and in two cases there was an underlying carcinoma. There were no major complications in this series.

Double-contrast cystography

J. R. Harding
St. Woolos Hospital, Newport

Newport and the South Gwent valleys have one of the highest incidences of bladder cancer in the United Kingdom. The intravenous urogram (IVU), while an essential investigation in patients with haematuria, is relatively poor for detecting and defining bladder tumours—many smaller tumours are not visualised at all, and the delineation of larger tumours is not optimal. Whilst sterile barium (Steripaque) was available in the past for cystography, it fell out of use mainly because of problems associated with reflux in paediatric patients. More recent improvements in mucosal imaging in the gastrointestinal tract by the double-contrast technique have prompted this study in the investigation of suspected bladder tumours; the development of modern, high-density barium preparations along with better image resolution due to improvement in radiographic equipment, high-definition films and rare-earth intensifying screens, have all contributed.

Patients are selected with a strong suspicion of bladder tumour because of painless haematuria, a filling defect in the bladder on an IVU, malignant cells in the urine, or a combination of these.

Papillary bladder tumours become coated densely with barium due to their large surface area, and are consequently very well visualised. It is usually easy to ascertain the exact number, site, size and shape of bladder tumours, and to determine whether they are polypoid.

A follow-up radiograph on the day after double-contrast cystography, initially performed to check that barium had been cleared from the bladder, shows selective residual coating of tumour with barium in a high proportion of cases, probably related to the papillary nature of these tumours, with barium retained in the interstices.

The technique has proved highly sensitive and specific (Table I) detecting tumours as small as 2 mm × 1 mm.

In the first 55 patients studied no tumours have been missed, and the one false-positive examination was due to misinterpretation of a ureterocele. There have been no complications. Double-contrast cystography has been shown to give useful pre-cystoscopic information, and has also proved helpful in areas inaccessible to cystoscopy, such as within narrow-necked diverticula, behind massively enlarged prostate glands, and within the bladders of patients who are unsuitable for cystoscopy because of anaesthetic risk, urethral strictures, or fixed flexion deformities of the hips.

It has been suggested, in view of the sensitivity of the technique, that a negative examination could preclude the need for cystoscopy thus sparing the patient a general anaesthetic; this is contentious and further evaluation is needed before it could be advocated.

TABLE I
CORRELATION OF DOUBLE-CONTRAST CYSTOGRAPHY WITH CYSTOSCOPY—55 PATIENTS

	D–C cystogram positive	D–C cystogram negative
Cystoscopy positive	36	0
Cystoscopy negative	1	18

Some observations on the Forrest report

G. H. Whitehouse (guest)
Liverpool University

The evidence for breast screening by mammography, which influenced the recommendations of the Forrest commission, was briefly discussed. It was noted that the Forrest report recommended screening for women aged 50–65 years. While extension to the 40–49-year-old age group would greatly increase the cost of a nationwide screening programme, evidence from the multicentre American BCDDP trial and our own study indicated that mammography was effective and justifiable in this younger age group. There was a need for an intense publicity campaign to give a high acceptance rate. Mobile units could play an important role, but should be entirely self-contained. Two radiographers, rather than the 1–1.5 WTEs recommended in the report, would result in a more rapid throughput. While clinical examination was not necessary, radiographers should document superficial features such as scars, moles and nipple discharge. Recent published series indicate that two-view mammography of each breast is superior to the single view recommended in the Forrest report, giving higher detection rate and lower number of recalls. Batch processing is recommended in the report, but there is a good case for instant processing. The radiographer would then exert effective and immediate quality control, which would add interest to repetitive work. The use of grids is a contentious issue in mammographic screening, improved mammographic quality being offset by an increased radiation dose. While a 3-year screening interval is recommended, 2-yearly screening is widely considered to be more appropriate. Difficulties are likely to be encountered in radiological staffing. The number of interested radiologists is unknown. The one to three sessions designated to each unit will generally have to be attached to new posts and would seldom be derived from existing posts. Furthermore, screening units do not necessarily conform to health authority boundaries. There are in summary, a large number of difficulties to resolve in a short period of time for the operation of an effective screening service.

The meeting was supported by May & Baker Ltd, E. Merck Ltd, Du Pont UK Ltd and Nycomed.

Press releases

BNFL appointment for Professor Roger Berry

Mr Peter Mummery, OBE, BNFL's Director, Health and Safety, is to retire on September 30, 1987 after 40 years of distinguished service to the nuclear industry. He is to be succeeded by Professor Roger Berry, 52, who has a worldwide reputation in the field of radiological protection.

As BIR members will know, Roger Berry is Professor of Oncology in the University College and Middlesex School of Medicine, University College, London, and he was BIR President for 1986–87. He is also a member of several international and national scientific bodies, including the International Commission on Radiological Protection, the National Radiological Protection Board, the Medical Research Council's Committee on the Effects of Ionising Radiation, the Radioactive Waste Management Advisory Committee and the Committee on Medical Aspects of Radiation in the Environment.

Mr Mummery joined the nuclear industry at Harwell in 1947 after graduating from Cambridge. He held senior appointments within the United Kingdom Atomic Energy Authority as Deputy Director of Winfrith and Director of Dounreay and was awarded the OBE in 1959 for his services to the nuclear industry. He joined BNFL as General Manager, North West Area, at the then Windscale and Calder works at the beginning of 1975. In April 1977 Mr Mummery moved to the company's headquarters at Risley, Warrington to establish the Health and Safety Directorate.

Health Technology for decision makers introduced by ECRI

Health Technology: Critical Issues for Decision Makers is a new, bimonthly journal from ECRI, a non-profit making organisation in health care technology research, evaluation, publishing and consulting. It is designed for hospital executives, heads of clinical departments and others interested in new health care technologies.

The new journal combines the most popular elements of ECRI's *Journal of Health Care Technology* and *Issues in Health Care Technology*, which have been merged into it.

Health Technology assists decision makers in evaluating new technologies by providing important clinical and technical details, as well as cost comparisons and practical recommendations, in a highly readable format. Consistent with ECRI's anti-conflict-of-interest policy, *Health Technology* will include no advertising. The subscription rate is $95 a year ($125 outside North America). For more information, contact the Circulation Department, ECRI, 5200 Butler Pike, Plymouth Meeting, PA 19462, USA.

Strong response to Medical/Hospitech '87

The trade exhibition of medical and hospital equipment, Medical/Hospitech '87, has attracted a large number of overseas companies. As of early March, manufacturers and suppliers from Australia, Austria, China, Great Britain, Japan, New Zealand, Spain, Switzerland, Taiwan, the United States and West Germany had already reserved space. Of particular note is the China National Corporation of Medical Equipment Industry, who seldom participate in international trade exhibitions overseas. They are occupying 500 square metres which is indicative of China's confidence in the potential of the Thai medical market.

The exhibition is to be held in the Bangkok International Exposition Centre, November 29–December 2, 1987. For further information, please contact: SHK International Services Ltd, 22/F, 151 Gloucester Road, Hong Kong. Tel: 5-8326107.

New "Newtron" available

Reactor Experiments Inc. is pleased to announce the availability of the 38th edition of the *Newtron*. This humorous newsletter is published with a focus on interesting applications of Reactor Experiments Inc. various metal foil and radiation protection products by their customers. Issue 38 includes a discussion of field-castable neutron shielding materials, which are used to shield in hard-to-access and awkwardly shaped volumes. These economical materials are often viable solutions to difficult shielding problems in terms of both ease of use and installation.

For more information, contact Reactor Experiments Inc., 963 Terminal Way, San Carlos CA 94070-3278, USA. Tel: (415) 592-3355. Telex: 34 5505. Fax: (415) 598-9555.

BIR calendar events

Unless otherwise indicated, enquiries about the following events should be addressed to the Conference Manager, British Institute of Radiology, 36 Portland Place, London W1N 4AT (Tel. 01-580 4085).

The meetings are at 36 Portland Place unless otherwise stated. Attendance is open to non-members.

Imaging in Dementia

October 15, 1987 at 5.30 p.m.
Organised by the Diagnostic Methods Committee.
Chairman: Dr P. J. Ell.
Speakers: Prof. R. Levy, Dr R. Wise, Dr P. J. Ell, Dr N. Antoun and Dr I. Moseley.

Chemical Modification of Radiation Effects: Experimental and Clinical

November 13, 1987 at 11.00 a.m.
All-day radiobiology work-in-progress meeting.

New Radiopharmaceuticals and Their Clinical Application

November 27, 1987
Scientific Societies, London W1
Organised by the Nuclear Medicine Subcommittee.
Speakers: Dr K. E. Britton, Dr I. Brown, Dr D. Le Bars, Dr B. Langström, Dr M. C. Lasne, Dr N. A. Lassen, Dr S. K. Luthra, Dr H. J. Machulla, Dr M. V. Merrick, Dr A. D. Nunn, Dr P. F. Sharp, Dr A. M. Verbruggen and Dr G. D. Zanelli.

Lasers—Applications in Radiology

January 14, 1988 at 5.30 p.m.
Joint BIR/RCR/RSM meeting.
Chairman: Dr W. D. Jeans.
Speakers: Dr A. L. Mackenzie, Dr D. C. Cumberland, Dr S. G. Bown, Mr D. Rothery, Dr G. Watson and Dr S. Hart.

Clinical Usefulness of Nuclear Medicine Image Processing

February 9, 1988
Joint IPSM/BIR meeting organised by the IPSM.
Further details: General Secretary, IPSM, 2 Low Ousegate, York YO1 1QU (Tel. 0904-610 821).

Functional Insights From Magnetic Resonance

February 17, 1988
University College and Middlesex School of Medicine, London, W1
Organised by the Diagnostic Methods Committee.
Chairman: Prof. B. S. Worthington
Speakers: Dr M. A. Smith, Mr D. Longmore, Dr I. Young, Dr D. Hadley, Prof. I. Isherwood, Dr S. Williams, Prof. R. H. T. Edwards, Dr B. Ross, Prof. O. Reynolds, Dr J. Cox and Dr V. R. McReady.

This meeting will incorporate the 1988 **Silvanus Thompson Memorial Lecture**, by Prof. P. Mansfield "Structural and functional investigations by real-time echo planar imaging". This will be open to non-registrants.

Radiobiology All-Day Non-topic Proffered Papers Meeting

February 19, 1988
Organised by the Radiobiology Subcommittee.

Too much Radiation in Radiodiagnosis?

March 9, 1988
University College and Middlesex School of Medicine, London, W1
All-day meeting organised by the Industry and Radiation Protection Committees.
Chairman: Dr J. G. Russell.

Total-Body Irradiation

April 13, 1988
Joint BIR/IPSM meeting organised by the BIR.

Conversazione

June 23, 1988
Institute of Directors, London SW1
Lecture by Sir George Pollock

Do *you* have something to say in the *Bulletin*?

Any item likely to be of interest to *Bulletin* readers (preferably brief) would be welcomed from BIR members. Please send material to: The Bulletin Editor, BIR, 36 Portland Place, London W1N 4AT. (Tel. 01-580-4189).

Library news

The BIR Library is open weekdays 9 a.m.–5 p.m. (7 p.m. on Thursdays)

The Librarian, Mrs Gunnel Ingham, is in attendance Tuesdays 11 a.m.–5 p.m., and Thursdays 11 a.m.–7 p.m., and Mrs Angela Lansdown, daily 9 a.m.–5 p.m. (Tel. 01-580 4085).

The journal stock includes more than 100 titles. Though journals may not be taken out of the library, there is a photocopy service, also available by post. A list of current journals is available on request and is also published in the March and September issues of the Bulletin. *Most books (excepting the historical collection) are available on loan.*

There is an agreement which allows BIR members limited use of the RSM Library for reference purposes. Members should apply to the BIR Librarian for a visitor's card.

Recent additions to the library

Ackery, D. & Batty, V. (Eds). Nuclear medicine in oncology. 1986
Ansell, G. Notes on radiological emergencies. 3rd edit. 1986
Bischof-Delaloye, A. & Blaufox, M. D. (Eds). Radionuclides in nephrology. 1987
Bondestam, S., Alanen, A. & Jouppila, P. (Eds). Euroson '87. Proceedings. 1987
Bragg, D. G., Rubin, P. & Youker, J. E. (Eds). Oncologic imaging. 1985
DHSS. Breast cancer screening. The Forrest report. 1986
Federle, M. P. & Brant-Zawadzki, M. Computed tomography in the evaluation of trauma. 2nd edit. 1986
Hansmann, M., Hackeloër, B. J. & Staudach, A. Ultrasound diagnosis in obstetrics and gynaecology. 1986
HMSO, Health and Safety Executive. Programmable electronic systems in safety related applications. 1. An introductory guide. 2. General technical guidelines. 1987
Hoogstraten, B. (Ed.). Hematologic malignancies. 1986
NCRP Report No. 81. Carbon-14 in the environment. 1985
NCRP Report No. 85. Mammography—a user's guide. 1986
NRPB. Living with radiation. 3rd edit. 1986
Philips Medical Systems. Digital subtraction angiography in clinical practice. 1986
Phillips, T. L. & Wara, W. (Eds). Radiation oncology. Vol. 2. 1987

Meetings and courses

As a service to our readers, the title, date and place of meetings and contact address will be inserted free of charge: any additional information will be charged at £1.75 per printed line, per insertion. Please contact the Managing Editor.

The British Cervical Spine Society
November 6–7, 1987
The Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry
Further details: Mr A. Crockard, The National Hospitals for Nervous Diseases, Maida Vale, London W9 1TL. Tel: 01-286 5172.

6th Annual Christie Hospital Symposium: Current controversies in radiotherapy
November 6–7, 1987
Further details: Dr B. Hancock, Consultant Radiotherapist, Christie Hospital, Wilmslow Road, Withington, Manchester M20 9BX.

9th London Ultrasound Course
November 9–13, 1987
Skyway Hotel, Hayes, Middlesex
Further details: Dr H. B. Meire, X-ray Department, King's College Hospital, Denmark Hill, London SE5 9RS.

International Symposium. Radiotherapy: Cure Without Multilation
November 20, 1987
Rotterdam, The Netherlands
Further details: C. Michielsen, c/o Organising Committee "Radiotherapy Symposium", The Dr Daniel den Hoed Cancer Centre, Rotterdam Radio-Therapy Institute, PO Box 5201, 30008 AE Rotterdam, The Netherlands.

Radiological Society of North America (RSNA). 73rd Scientific Assembly and Annual Meeting
November 29–December 4, 1987
Chicago, Illinois, USA
Further details: Mr G. Schuyler, RSNA, 1415 W 22nd Street, Tower B, Oak Brook, Illinois 60521, USA. Tel: (312) 920 2680.

International Symposium on New Developments in Head and Neck Cancer
December 2–4, 1987
Free University, Amsterdam, the Netherlands
Further details: Prof. Dr G. B. Snow, Department of Otolaryngology, Free University Hospital, de Boelelaan 1117, 1081 HV Amsterdam, the Netherlands.

BMUS 19th Annual Scientific Meeting
December 8–10, 1987
Brighton
Further details: Dr R. J. Burwood, Department of Radiology, Royal Sussex County Hospital, Brighton, Sussex BN2 5BE.

9th Conference on Medical Physics
December 10–12, 1987
Trivandrum, India
Further details: Dr A. S. Pradhan, Convener, Scientific Programme Committee, 9th Conference on Medical Physics, Division of Radiological Protection, Bhabha Atomic Research Centre, Bombay—400 085, India.

Nuclear Medicine—Biannual Intensive Course
January 29–30, 1988
UMDS St Thomas's Hospital Medical School Postgraduate Centre, London
Further details: Miss Erica Mendy, Postgraduate Secretary, St Thomas's Hospital, Lambeth Palace Road, London SE1 7EH. Tel: 01-928 9292 ext 2072.

International Congress: Interventional Radiology in Cardiovascular Diseases
February 3–5, 1988
Toulouse, France
Further details: Professor F. Joffre, Service de Radiologie, Chu Rangueil, Chemin du Vallon, 31054 Toulouse Cedex, France. Tel: 6155 4478 ext. 3081-3047.

6th International Meeting on Chemical Modifiers of Cancer Treatment
March 21–25, 1988
Paris, France
Further details: Dr E. P. Malaise, Laboratoire de Radiobiologie Cellulaire (Unité Inserm 247), Institut Gustave-Roussy, 94805 Villejuif Cedex, France

Radiation Research Society, 36th Annual Meeting
North American Hyperthermia Group, 8th Annual Meeting
April 16–21, 1988
Philadelphia, Pennsylvania
Further details: Radiation Research Society, 1101 Market Street, 14th Floor, Philadelphia, PA 19107, USA. Tel: 215-574-3153.

Fifth International Symposium on the Planning of Radiological Departments
April 20–23, 1988
Florence, Italy
Further details: ISPRAD V Organizing Secretariat, CLAS Editoriale, Via Pace 8, 25122 Brescia, Italy.

3rd International Symposium on Neutron Capture Therapy
May 31–June 3, 1988
Bremen, FR Germany
Further details: Prof. Dr D. Gabel, Dept of Chemistry, University of Bremen, Box 330 440, D-2800 Bremen 33, FR Germany

4th International Symposium on Radiation Physics
October 3–7, 1988
Sao Paulo, Brazil
Further details: Prof. Dr I. Nascimento Director, Instituto de Fisica, Universidade de Sao Paulo, Cicade Universitaria, C. P. 20516, Sao Paulo, Brazil.

Workshop: Progress in Regional Cancer Therapy
November 3–5, 1988
Vienna, Austria
Further details: c/o B. Schick, Abteilung für Experimentelle, Chirurgie der I. Chirurgischen Universitätsklinik, Alser Strasse 4, A-1090 Vienna, Austria (Tel. 0222-4800/2301).

12th World Conference on Non-destructive Testing
April 23–28, 1989
Amsterdam
Further details: 12th WCNDT 89, c/o Organisatie Bureau Amsterdam bv, Europaplein 12, 1078 GZ Amsterdam. Tel: (31)20-440807

Instructor/Assistant Professor
Rhode Island Hospital

The Department of Radiation Medicine of the Rhode Island Hospital, a teaching unit of Brown University, is recruiting for a full-time academic Radiation Therapist. The successful candidate must qualify for a faculty appointment at Brown University at the level of Instructor/Assistant Professor in the Department of Radiation Medicine.

The individual should possess a medical degree and be board certified or eligible. This individual should evidence an expertise in patient care based upon a highly qualified training programme. The person must have demonstrated the capacity for scholarship and is expected to begin an involvement in either basic or clinical research. There should be some comments, in letters of recommendation, regarding the individual's ability to teach, albeit specific documentation of teaching ability may not be required because of the difficulty of access of the Radiation Therapy Department to didactic courses in most medical schools. In addition, the individual must evidence an interest and a willingness to relate to the private sector of radiation medicine and surgical oncology in order to be a major focus of the coordinated research programme utilizing the patient resources of both the full- and part-time voluntary sector at Brown.

The Department opened in 1973, and is staffed by a complement of eight certified Radiation Therapy technologists, and equipped with the latest therapy units, including a 10 MeV, 6 MeV and a 4 MeV linear accelerator. The Department has a Toshiba Simulator with fluoroscopic capability and transverse tomography. Full-time physics staff in the Section of Physics including one PhD physicist and two dosimitrists. The Department has a Section of Computer Sciences with the latest in computer equipment, including PDP 11 and a new VACS 11750 system. The Department also includes a Psychosocial Programme with a liaison psychiatrist and a psychiatric social worker. In excess of 1200 patients a year are treated, and this is expected to increase very closely with the Department of Medical Oncology and with the various surgical subspecialties in combined modality treatment programmes and in Phase II and Phase III cooperative clinical trials, most of which are associated with national and international cooperative groups which the Department is associated with. Basic research opportunities could be made available for those who have a specific interest in laboratory research. The Department of Radiation Therapy is under the direction of Dr. Melvin Tefft.

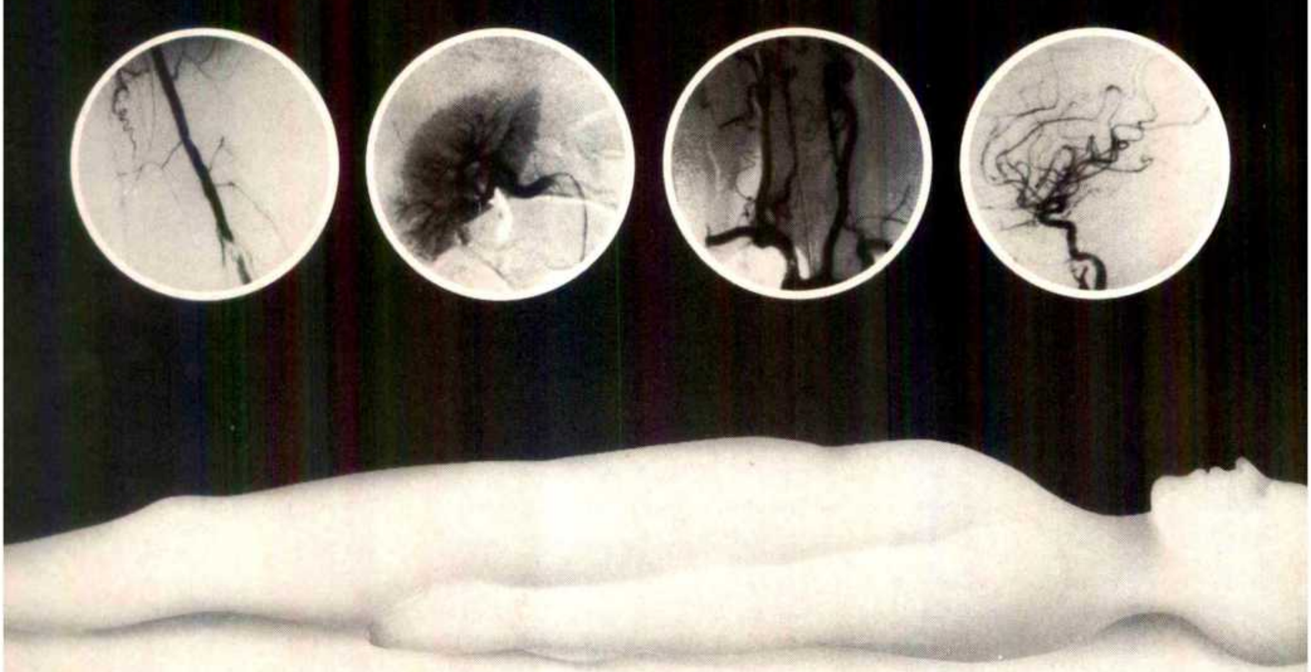
Inquiries, along with current curriculum vitae, should be directed to Dr. Melvin Tefft. Thereafter, candidates will be asked to visit Providence (at the expense of the Department of Radiation Therapy) for interviews prior to the final selection of this position. Applications must be submitted no later than 31st December, 1987.

Mailing address:

Department of Radiation Therapy
Rhode Island Hospital
593 Eddy Street
Providence, RI 02903

The Rhode Island Hospital is an EEO/AA employer and invites applications from minority and protected groups.

Digital Subtraction Angiography



Outstanding Picture Quality at a Low Price

Quantel's totally new concepts in video processing, developed over 15 years for the TV world, make IDIS a truly revolutionary product. Previously time consuming and complicated angiography tasks can now be performed in seconds — and you don't have to be a computer programmer to operate IDIS. As the development costs were borne by the broadcast industry the price for IDIS is surprisingly attractive.

IDIS is easy to install too. All you need is a simple coaxial cable connected to the fluoroscopic output of your system. No air conditioning or special power is needed, just plug it in to a standard domestic socket and IDIS is ready for action. Use of high density multi-layered printed circuits result in a small compact unit — easily wheeled from room to room.

For the technically minded, IDIS uses — Analogue/Digital converters to digitise signals at 10 million samples per sec; Recursive Video Processor for real-time noise reduction; State-of-the-art 32 bit microprocessors for fast digital calculation; 168 Mbyte Winchester disks for vast picture library; new technology 10 Mbyte removable floppy disk cartridges. Features such as Matched Temporal Filtering, Spatial Filtering, Interpolated Zoom and Dynamic Contrast Adjustment give startlng picture clarity and versatility to optimise accurate diagnosis.

IDIS leads the field in DSA and is backed by Quantel's world acclaimed service.

– for innovative medical imaging

IDIS

QUANTEL, 21 Turnpike Road, Newbury, Berkshire RG13 2NE. Tel: (0635) 32222

(continued from outside back cover)

Reply 1041
G. Johnson, I. E. C. Ormerod, D. Barnes, P. S. Tofts and D. MacManus
Divergence of opinion over the linear-quadratic model 1042
O. C. A. Scott
Proceedings of The British Institute of Radiology
Radionuclide investigations of the lung, February 11, 1987 1044

Book reviews

Diagnostic imaging of the chest. *P. R. Goddard* 956
Magnetic resonance of the musculoskeletal system. *T. H. Berquist, R. L. Ehman and M. L. Richardson* (Eds) 956
Pediatric imaging/Doppler ultrasound of the chest: extracardiac diagnosis. *J. C. Huhta* 956
A colour atlas of angina pectoris. *L. M. Shapiro, C. A. Warnes and K. M. Fox* 980
Radiology of congenital heart disease, Vol. 1. *K. Amplatz, J. H. Moller and W. R. Castañeda-Zuniga* 980
Cardiac imaging: new technologies and clinical applications. *M. N. Kotler and R. M. Steiner* (Eds) 980
Notes on radiological diagnosis. *L. S. W. Lau and J. F. De Campo* 996
New developments in imaging. *R. Ch. Otto and C. B. Higgins* (Eds) 996
Teaching atlas of mammography, 2nd revised edit. *L. Tabár and P. B. Dean* 996
Herbert M. Parker: publications and other contributions to radiological and health physics. *R. L. Kathren, R. W. Baalman and W. J. Bair* (Eds) 1000
Radiology of lymphomas. *J.-N. Bruneton and M. Schneider* (Eds) 1000
Brain tumours. Their biology and pathology, 3rd edit. *K. J. Zülch* 1010
Imaging of the temporal bone: a text/atlas. *J. D. Swartz* 1010
Ultrasound atlas: real-time ultrasound imaging in internal medicine. *H. Weiss and A. Weiss* 1034
Atlas of radiologic anatomy, 4th edit. *L. Wicke* 1034
Endourology, principles and practice. *A. D. Smith, W. R. Castañeda-Zuñiga and J. G. Bronson* (Eds) 1034

BIR Bulletin and Calendar events *facing page* 1048

Featured in the next issue

Seeing things more clearly (The Mayneord Lecture 1986)
G. R. Higson
Evaluating and comparing imaging techniques. A review and classification of study designs
L. S. Freedman
Use of a microcomputer for the estimation of X-ray dose received by the fetus
D. McG. Clarkson and S. E. Bronnan
The influence of field size on the late tolerance of the rat spinal cord to single doses of X rays
J. W. Hopewell, A. D. Morris and A. Dixon-Brown
Short communication: The use of endoscopic ultrasound and laser photocoagulation in the treatment of gastrointestinal tract tumours
A. C. Steger, S. E. S. Whitecross and N. Hira
Correspondence: Increased potential for tissue discrimination in quantitative magnetic resonance imaging
D. J. Prendergast, J. P. R. Jenkins, D. S. Hickey and I. Isherwood

VOL 60 NO 718 OCTOBER 1987

The British Journal of Radiology

Contents

Page

The institute at 90: a time for reappraisal? (1986–87 Presidential Address) 947
R. J. Berry

Magnetic resonance imaging in the evaluation of nose and paranasal sinus disease 957
G. A. S. Lloyd, V. J. Lund, P. D. Phelps and D. J. Howard

A comparison of angiographic and electrocardiographically gated computed tomographic measurements of left-ventricular function 969
C. J. Foster, W. C. Brownlee, J. F. Griffin, J. Yates, H. G. Love and I. Isherwood

Pitfalls in interpretation of computed tomography prior to second-look laparotomy in patients with ovarian cancer 975
A. R. Calkins, F. B. Stehman, J. L. Wass, L. R. Smirz and J. H. Ellis

The measurement of heart size in the antero-posterior chest radiograph 981
J. E. Kabala and P. Wilde

Radiology of normal and abnormal gastric mucus 987
E. Samuel

Congenital diaphragmatic hernia: the prognostic significance of the site of the stomach 993
T. Goodfellow, I. Hyde, D. M. Burge and N. V. Freeman

Position of the superior mesenteric artery on computed tomography and its relationship to retroperitoneal disease 997
B. M. Carrington and D. F. Martin

A set of X-ray test objects for image quality control in digital subtraction fluorography. I: design considerations 1001
A. R. Cowen, J. M. Haywood, A. Workman and O. F. Clarke

A set of X-ray test objects for image quality control in digital subtraction fluorography. II: application and interpretation of results 1011
A. R. Cowen, A. Workman, J. M. Haywood and O. F. Clarke

Technical notes

Use of a simple Leeds test object for rapid assessment of image intensifiers 1019
A. M. Grant, T. M. Kehoe and J. Law

A simple technique for double-contrast oesophagrams 1021
P. M. F. Yoong

Case reports

Idiopathic spinal arachnoid cyst and syringomyelia 1023
A. G. Clifton, L. Ginsberg, W. J. S. Webb and A. R. Valentine

Radiographic appearance of frontal osteomyelitis in two patients with extradural abcess 1026
A. M. Belli, C. J. Dow and P. Monro

Demonstration of a matrix calculus using computed tomography 1028
P. W. Sheppard and F. E. White

Appendix mass in AIDS? 1030
S. H. Lee, M. A. Hall-Craggs and W. R. Lees

Sclerosing stromal tumour of the ovary 1031
N. Kawamura, I. Kamoi and R. Shigyo

Case of the month

A lump on the thigh 1035
M. Crone and I. Watt

Short communication

Vascular injury in the mouse rectum after irradiation and cis-diamminedichloroplatinum (II) 1037
L. Dewit and Y. Oussoren

Correspondence

Accuracy and precision in the measurement of relaxation times from nuclear magnetic resonance images 1041
J. P. R. Jenkins, D. S. Hickey and I. Isherwood

(continued on inside back cover)

© 1987: The British Institute of Radiology. This publication is copyright under the Berne Convention and the Universal Copyright Convention. All rights reserved, apart from any relaxations permitted under national copyright laws, no part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means without the prior permission of the copyright owners. Permission is not, however, required to copy abstracts of papers or of articles on condition that a full reference to the source is shown. Multiple copying of the contents of the publication without permission is always illegal. Published by The British Institute of Radiology, 36 Portland Place, London W1N 4AT. Printed in Great Britain by The Whitefriars Press Ltd., Tonbridge. ISSN 0007 1285

Volume 60 Number 719
November 1987

Acc.
22.8.88

THE BRITISH JOURNAL OF RADIOLOGY

X-ray diagnosis
Radiotherapy
Nuclear medicine
Ultrasound
Nuclear magnetic resonance
Radiological physics
Radiobiology
Oncology
Hyperthermia
Radiation protection

LIBRARY

Published by

The British Journal of Radiology

FOUNDED 1896

The Editorial Committee consists of:

The Editors:

J. T. PATTON, F.R.C.P., F.R.C.R. N. J. MCNALLY, B.SC., M.SC., PH.D.

The Deputy Editors:

D. G. SHAW, F.R.C.P., F.R.C.R. C. K. BOMFORD, B.SC., M.PHIL., F.INST.P.

and

The Associate Editors:

J. E. ADAMS, M.B., B.S., M.R.C.P., F.R.C.R.
P. R. BLAKE, M.B., B.S., B.SC., F.R.C.R.
J. A. BULLIMORE, M.B., B.S., M.R.C.S., L.R.C.P., D.M.R.T., F.R.C.R.
P. DAWSON, B.SC., PH.D., M.B.B.S., M.R.C.P., M.INST.P., F.R.C.R.
S. DISCHE, M.D., F.R.C.R.
F. A. DUCK, PH.D., M.I.E.E.E.
A. H. FREEMAN, M.B., B.S., F.R.C.R.
R. M. HARRISON, B.SC., M.SC., PH.D., M.INST.P.
J.W. HOPEWELL, B.SC., PH.D.
W. D. JEANS, M.B., B.S., F.R.C.R.
C. H. JONES, B.SC., PH.D., F.INST.P.
D. M. KING, M.B.B.S., F.R.C.R., D.M.R.D.
H. W. C. LOOSE, D.M.R.D., F.R.C.R.
D. W. PILLING, M.B., CH.B., D.C.H., D.M.R.D., F.R.C.R.
M. J. RAPHAEL, M.A., M.D., F.R.C.P., F.R.C.R., D.M.R.D.
J. R. K. SAVAGE, D.SC.
R. A. SHIELDS, PH.D.
A. R. VALENTINE, M.B., B.S., M.R.C.S., L.R.C.P., F.R.C.R., D.M.R.D.
G. H. WHITEHOUSE, M.B., B.S., F.R.C.P., F.R.C.R., D.M.R.D.
A. G. WILSON, F.R.C.P., F.R.C.R.
E. P. WRAIGHT, M.B., B.CHIR., PH.D., D.M.R.T.

The Associate Editors Overseas are:

P. ARMSTRONG, M.B., B.S., F.R.C.R., D.M.R.D. (North America)
H. K. BADDELEY, M.B., B.S., D.M.R.D., F.R.C.R., M.R.A.C.R. (Australasia)
S. G. A. CHENERY, PH.D., F.C.C.P.M. (North America)
B. J. CREMIN, F.R.C.R., F.R.A.C.R. (South Africa)
R. FOX, D.PHIL. (Australia)
M. TAKAHASHI, M.D. (Japan)
D. M. TAYLOR, D.SC., C.CHEM., F.R.S.C. (Continental Europe)

Managing Editor: LYNN WHITFIELD, B.SC.

Communications should be addressed to the Editors in accordance with the Instructions to Authors which are published in the January issue of the Journal in each year and copies of which may be obtained on application to the Managing Editor.

ADVERTISEMENTS: Communications should be addressed to Advertising Dept., The British Journal of Radiology, 36 Portland Place, London W1N 4AT (01-631 1168).

SUBSCRIPTIONS: All communications should be sent to The British Institute of Radiology, 36 Portland Place, London W1N 4AT, England. Notification of change of address should include an old mailing label and the new address. Claims for missing copies can only be allowed if received within four months of normal delivery date.

ANNUAL SUBSCRIPTION: £90 per annum, payable in advance (USA, $159/India, £94). Single copies: £10.00 (available from UK office).

USA, Canada, Central and South America, Mexico, West Indies: Orders to British Journal of Radiology, P.O. Box #2513, Birmingham, Alabama 35201, USA.

Air-speeded delivery. Second class postage paid at Rahway, N. J. Postmaster: send address corrections to The British Journal of Radiology, c/o Mercury Airfreight International Ltd Inc., 10B Englehard Avenue, Avenel, NJ 07001. British Journal of Radiology (ISSN 0007-1285), monthly.

India: Orders to Universal Subscription Agency Pvt. Ltd., 101–102 Comm. Centre, PB No. 8, Malviya, Nagar Extn., Saket, New Delhi 110017, India (air-speeded delivery).

The British Institute of Radiology

Incorporated by Royal Charter
PATRON: HER MAJESTY THE QUEEN

Founded 1897

36 PORTLAND PLACE, LONDON W1N 4AT
Telephone: 01-580 4085 and 01-580 4189. Cable Address: "Britology, London W.1."

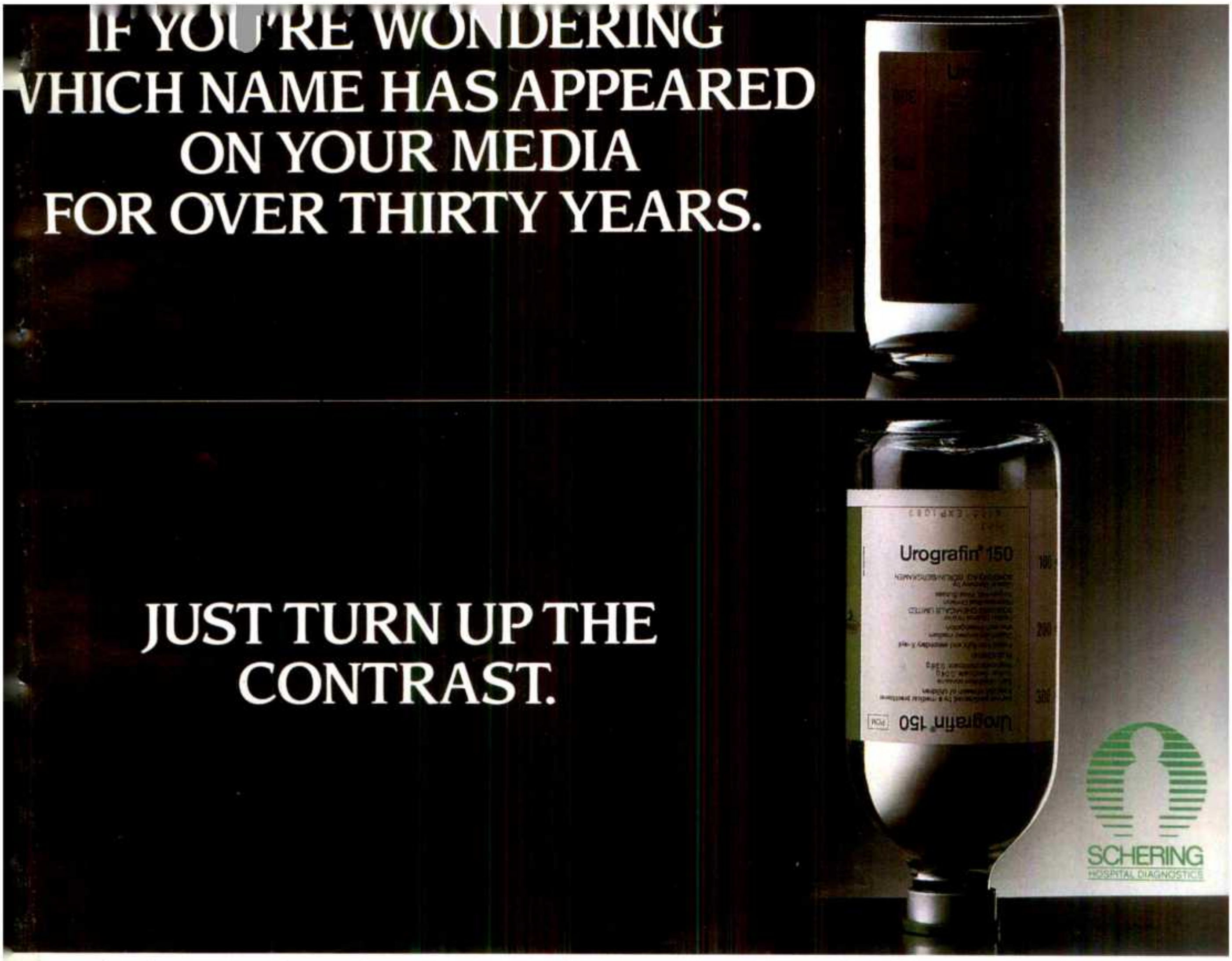
President: G. MOUNTFORD, M.C.A.M., D I P.M., M.B.I.M., D.C.R.

Hon. Secretaries:

M. GOWLAND, M.B., CH.B., F.R.C.R., M.R.C.P. (HON.)
M. J. HARVEY, T.D.C.R., D.M.S.

General Secretary: SUSAN M. JOHNSTONE, B.A.

THE BRITISH INSTITUTE OF RADIOLOGY is an association of persons interested in Radiology and allied subjects. Meetings are held monthly from October until May. Particulars of membership and other information may be obtained on application to the General Secretary at the Institute.



Schering experience in contrast media shows in the carefully selected range of sizes and presentations in which Urografin 150 is supplied. In ampoules or bottles, Urografin 150 is available in the volumes needed for a wide range of radiographic investigations – so that the administration procedure is not interrupted by the distraction of changing bottles. The 500ml size, for example, is specially produced for cystography and videocystometry.

Urografin has been proved by thirty years of experience to give acceptable tolerance, first-class contrast and a low incidence of side-effects at a very modest cost.

In contrast media, experience tells.

Urografin 150

Schering. Clearly a first-class choice.

PRESCRIBING INFORMATION UROGRAFIN 150 – Presentation: An intravenous injection of meglumine diatrizoate 26.1% w/v and sodium diatrizoate 3.9% w/v containing 146mg iodine/ml. **ses:** X-ray contrast medium for the delineation of the vascular and renal systems. **Dosage and Administration:** Drip-infusion urography 2-4ml/kg body weight up to 250ml, retrograde urography 5-10ml, Cystography up to 500ml. **Contra-indications:** Proven or suspected hypersensitivity to iodine-containing contrast media; manifest thyrotoxicosis; decompensated cardiac insufficiency; hysterosalpingography during pregnancy; acute pelvic inflammation. **Warnings, etc:** Carefully consider need for examination if there is: Severe impairment of hepatic or renal tion; cardiac or circulatory insufficiency; cerebral arteriosclerosis; cerebral spasmodic conditions; epilepsy; juvenile-onset or long-standing diabetes; pulmonary emphysema; poor general th; hyperthyroidism; multiple myeloma; a history of allergy. Since safety during pregnancy is not certain, X-ray examinations should be done only if essential. Allergic patients may be ersensitive. Particular caution in allergic persons who have tolerated a contrast medium without complication; they may have become sensitized. Contrast media and anti-allergic agents t not be mixed. In patients with multiple myeloma, juvenile-onset or long-standing diabetes, polyuria, oliguria, gout or marasmus, and in infants and young children, fluids should not be tricted. Disturbances of water and electrolytes must first be corrected. Premedication with an alpha-blocker is recommended in patients with phaeochromocytoma. Administer Urografin 150 y to recumbent patients, and closely observe for at least 15 minutes. If not already on the X-ray table, those with labile circulations should be brought to the table sitting or lying. Urografin 150 ices the capacity of the thyroid to take up iodine for a few days, and sometimes up to 6 weeks. Mild symptoms, such as heat and nausea, disappear rapidly when the injection is slowed down terrupted. Transient pain may occur, in particular during peripheral vascular examinations. Extravasations rarely cause serious tissue reactions. If marked side-effects or suspected allergic tions occur during injection, and do not disappear, or even worsen, when it is interrupted, stop the investigation. Even minor symptoms such as itching, sneezing, violent yawns, tickling in throat, hoarseness or coughing may be early signs of a severe reaction. Very rare severe or life-threatening side-effects include hypotensive collapse, circulatory failure, ventricular llation, cardiac arrest, pulmonary oedema, anaphylactic shock or other allergic manifestations, and convulsions or other cerebral symptoms. **Basic NHS price:** 10 x 10ml: **£11.25;** 10 x 20ml: **.75;** 1 x 250ml: **£9.21;** 1 x 500ml: **£18.00.**

---

duct Licence no.: 0053/5041. Product Licence holder: Schering Pharmaceuticals, Division of Schering Health Care Limited, The Brow, Burgess Hill, West Sussex RH15 9NE. Telephone: 04446 6011.

elscint
The Image You Can Rely On

Magnetic Resonance Imaging

Computed Tomography

Nuclear Medicine

Ultrasound

Mammography

ELSCINT (G.B.) LTD
Tower Road, Berinsfield, Oxfordshire OX9 8LW
Tel: Oxford (0865) 340900
Fax: Oxford (0865) 341252 Telex: 83341

DIGITAL IMAGING DG 200 - DG 300

a new system of digital imaging

DG 200: General vascular - DG 300: Cardio vascular • Quality • Speed • Simplicity

THOMSON CGR

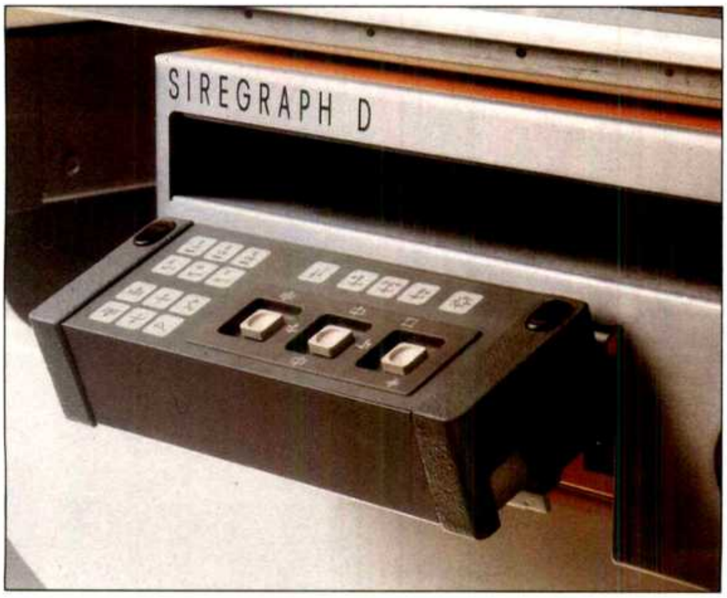
THOMSON - CGR, ASTRONAUT HOUSE, HOUNSLOW ROAD, FELTHAM, MIDDLESEX, TW 149 AD

SIEMENS

SIREGRAPH D from Siemens –
The remote controlled fluoroscopy table

SIREGRAPH D® represents a new generation of remote controlled tables, setting a new standard in overtable fluoroscopy. Features of the SIREGRAPH D include:

- Advanced and reliable microcomputer technology for the entire control system.
- Silk smooth continuously variable speed control in both acceleration and deceleration.
- Ergonomically designed remote control desk with comfortably placed controls.
- Detachable tableside infra-red control for working near to or remote from the patient.
- Digitally controlled spot film device with flexible multi format cassette programme for maximum film utilization.



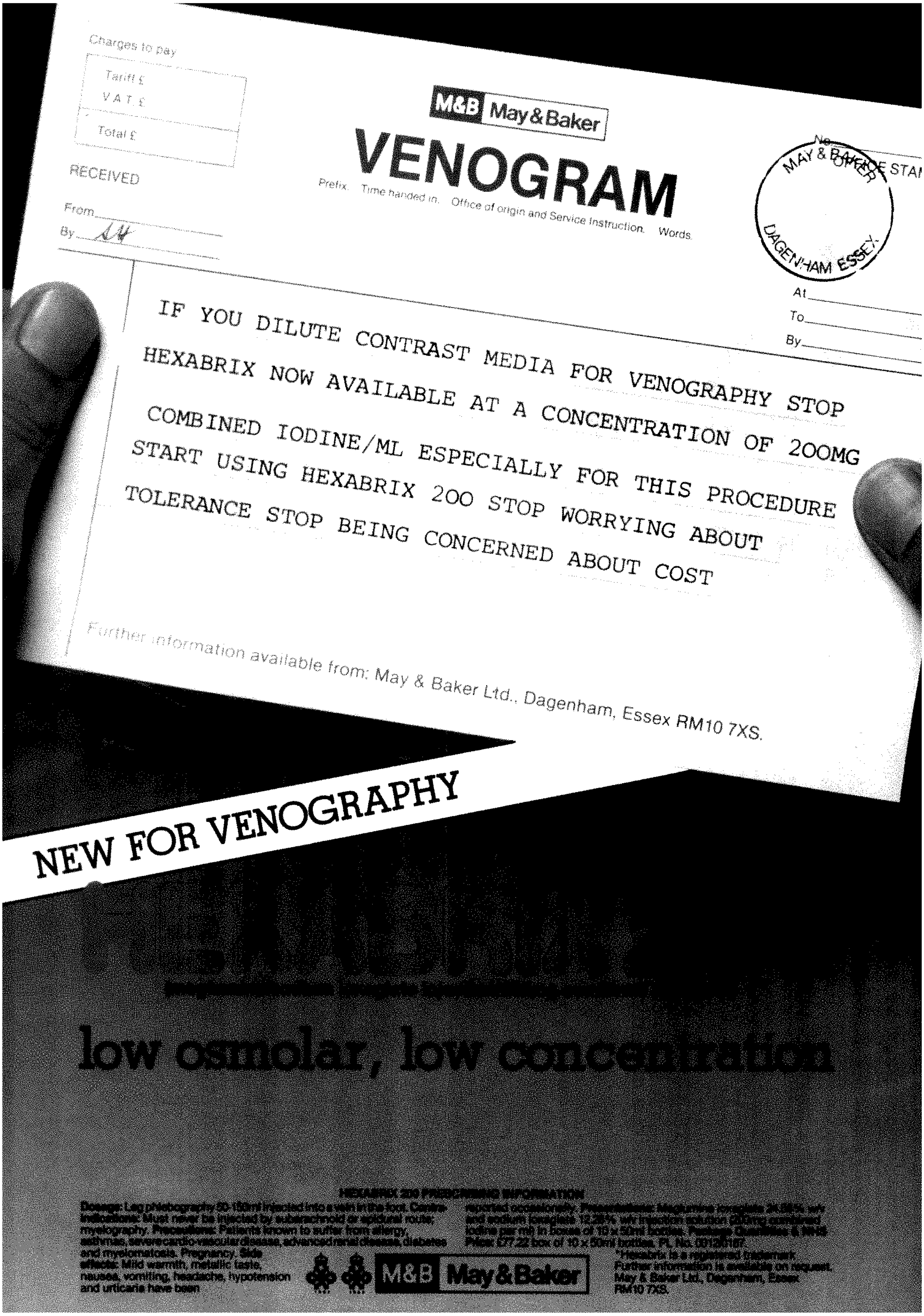
SIREGRAPH D is available in a choice of versions with or without lifting base and differing Trendelenburg.

It is the first table of its kind to incorporate fibre-optics for cost effective and reliable connection to the x-ray generator, and utilises microcomputers to control and monitor all functions.

For more information contact:

Siemens Limited
Medical Division
Siemens House
Windmill Road
Sunbury-on-Thames
Middlesex TW16 7HS
Telephone: (0932) 785691
Telex: 8951091

Setting Standards in Remote Control Tables . . . Siemens



Charges to pay

Tariff £

V.A.T. £

Total £

RECEIVED

From

By

M&B May&Baker

VENOGRAM

Prefix. Time handed in. Office of origin and Service Instruction. Words.

No.

MAY & BAKER STA

DAGENHAM ESSEX

At

To

By

IF YOU DILUTE CONTRAST MEDIA FOR VENOGRAPHY STOP
HEXABRIX NOW AVAILABLE AT A CONCENTRATION OF 200MG
COMBINED IODINE/ML ESPECIALLY FOR THIS PROCEDURE
START USING HEXABRIX 200 STOP WORRYING ABOUT
TOLERANCE STOP BEING CONCERNED ABOUT COST

Further information available from: May & Baker Ltd., Dagenham, Essex RM10 7XS.

NEW FOR VENOGRAPHY

[illegible]

low osmolar, low concentration

HEXABRIX 200 PRESCRIBING INFORMATION

Dosage: Leg phlebography 50-150ml injected into a vein in the foot. **Contra-indications:** Must never be injected by subarachnoid or epidural route; myelography. **Precautions:** Patients known to suffer from allergy, asthma, severe cardio-vascular disease, advanced renal disease, diabetes and myelomatosis. Pregnancy. **Side effects:** Mild warmth, metallic taste, nausea, vomiting, headache, hypotension and urticaria have been reported occasionally. **Presentations:** Meglumine ioxaglate 24.56% w/v and sodium ioxaglate 12.28% w/v injection solution (200mg combined iodine per ml) in boxes of 10 x 50ml bottles. **Package Quantities & NHS Price:** £77.22 box of 10 x 50ml bottles. PL No. 0012/0187.

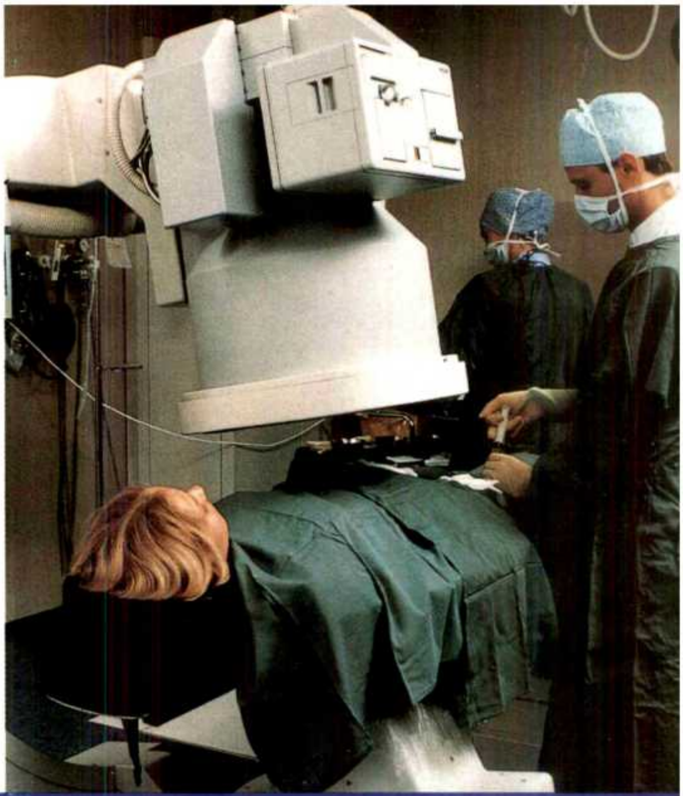
M&B May&Baker

*Hexabrix is a registered trademark.
Further information is available on request.
May & Baker Ltd., Dagenham, Essex
RM10 7XS.

When you are in a therapeutic or diagnostic vascular routine good support is invaluable. DVI-S provides your radiographic technician with the means to give full support by managing images through infra-red control from any position.

During the procedure there is instantaneous monitor review of the acquired runs and easy selection and display of reference images or roadmaps on a second monitor.

Real-time digital image processing enhances the fluoroscopic image so that fine catheters and guidewires can be clearly seen, while the unique dye-trace subtraction fluoroscopy provides the perfect roadmap for precise positioning.



If both your hands are tied,
DVI-S gives you another

DVI-S is the latest DSA answer to the growing demand for improved interventional procedures.

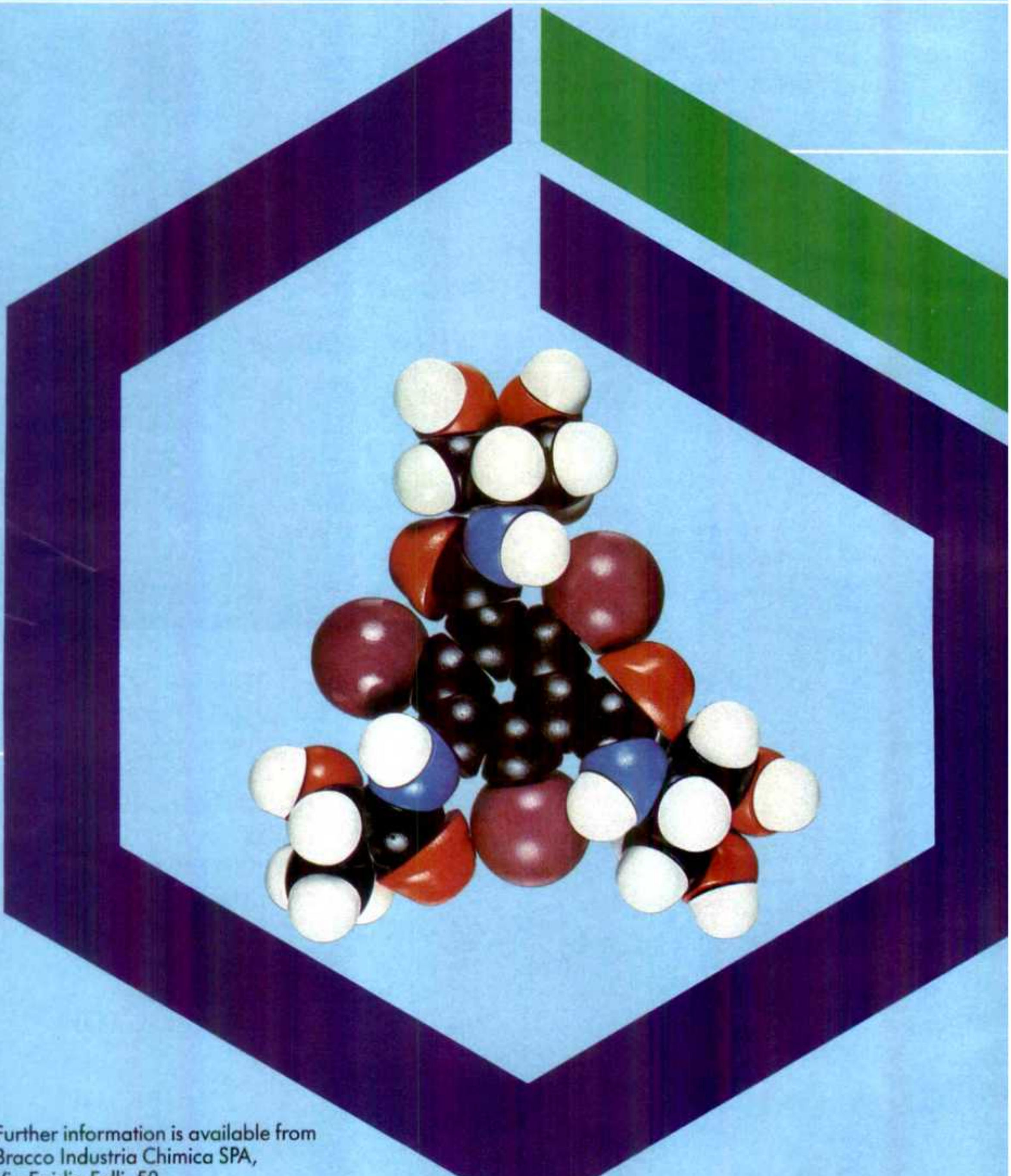
Philips Medical Systems
Kelvin House
63-75 Glenthorne Road,
Hammersmith,
LONDON, W 6 OLJ

Philips Medical Systems
Building QM, P.O. Box 10000,
5680 DA Best
The Netherlands

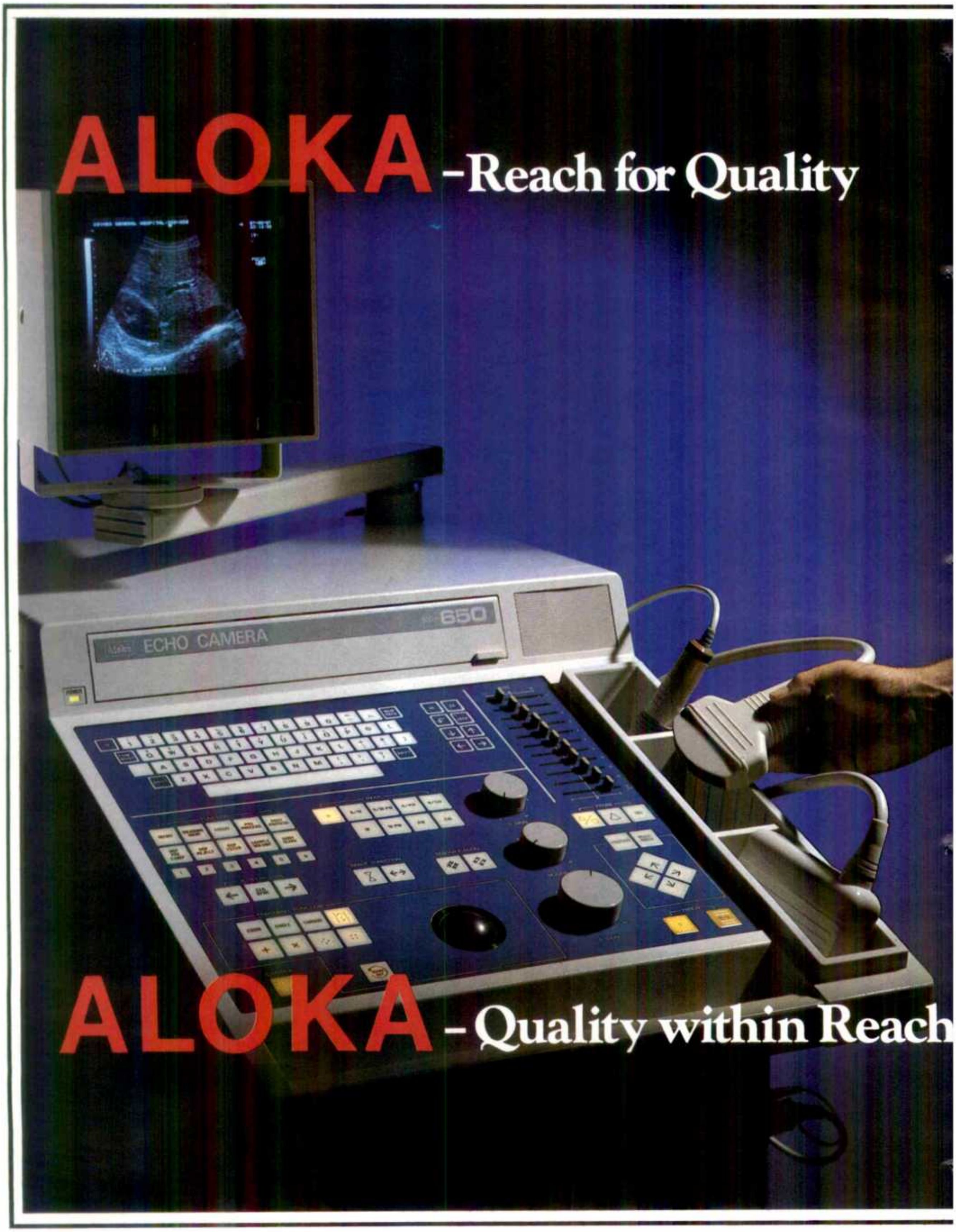
PHILIPS Medical Systems

PHILIPS

IOPAMIDOL



Further information is available from
Bracco Industria Chimica SPA,
Via Egidio Folli, 50,
20134 Milano, Italy


ALOKA -Reach for Quality
ECHO CAMERA
650
ALOKA - Quality within Reach

KeyMed -Reach for Support

KeyMed is setting new standards:

* For excellent image quality with the Aloka SSD-650.

* For providing ergonomically designed Aloka probes for every application.

* For versatility – demonstrated by the Aloka SSD-600 series, available with the probes of your choice.

* For breast scanning with the Aloka SSD-121E high resolution small part scanner.

* For endosonography with rigid and flexible probes.

* For colour doppler with the Aloka SSD-860 second generation cardiac scanner.

* For portability – the Aloka SSD-210DXII, remarkable for its size, quality and price.

* For service and support – committed to providing only the best back-up for our customers.

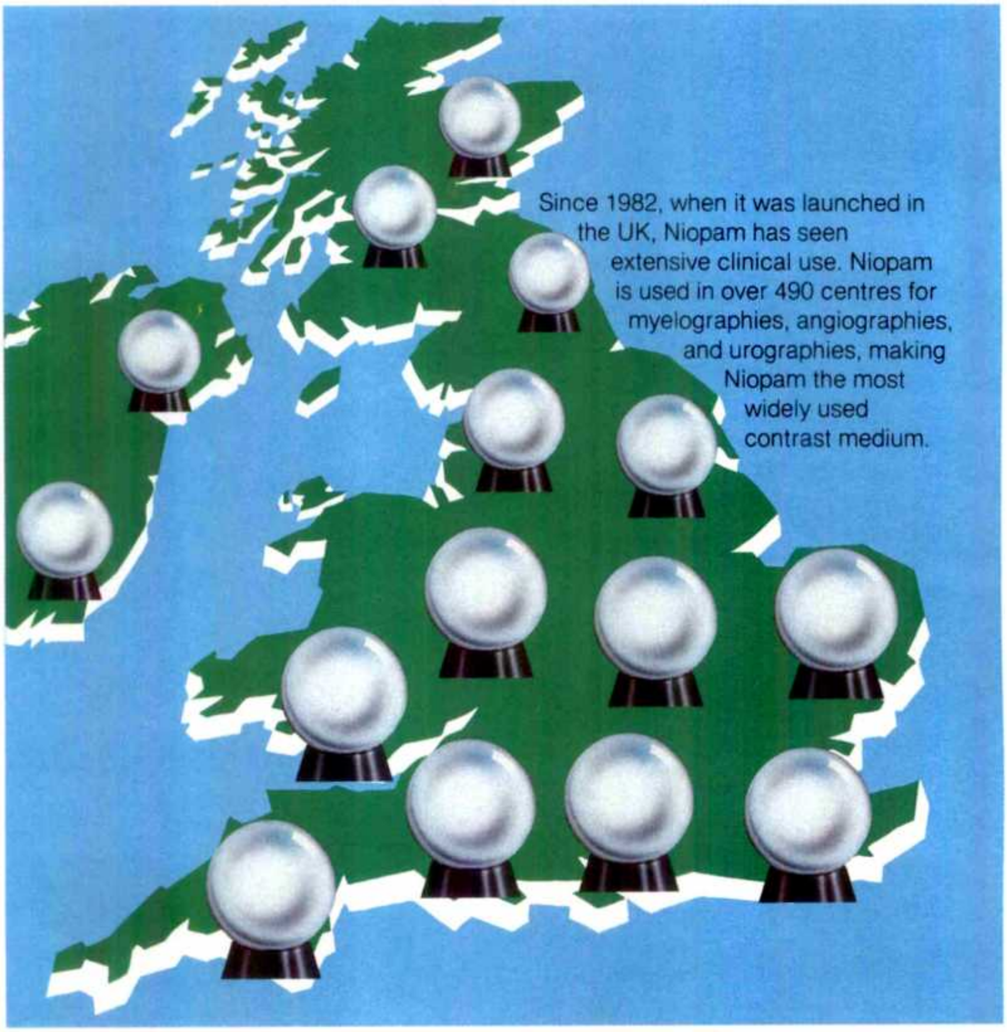
KeyMed -Support within Reach

Specialised Services to Medicine
KeyMed (Medical & Industrial Equipment) Ltd.
KeyMed House, Stock Road, Southend-on-Sea, Essex SS2 5QH.
Telex: 995283, Facsimile: (0702) 65677, Telephone: (0702) 616333 (24 lines).

Scotland: KeyMed, Peel House, Ladywell East, Livingston EH54 6AH. Telephone: (0506) 416655

Ireland: KeyMed Ireland Ltd., KeyMed House, Lord Edward Court, Bride Street, Dublin 8. Telephone: 774855

USA: KeyMed Inc., 400 Airport Executive Park, Spring Valley, New York 10977. Telephone: (914) 425-3100



Since 1982, when it was launched in the UK, Niopam has seen extensive clinical use. Niopam is used in over 490 centres for myelographies, angiographies, and urographies, making Niopam the most widely used contrast medium.

Niopam

iopamidol

Angiography Myelography Urography
Now the most widely used contrast medium

Angiography, myelography, urography — all procedures that you may carry out every day. For all of them, you can use Niopam — the first stable, water soluble, non-ionic contrast medium. Extensive clinical use has established Niopam's safety and acceptability,[1,2,3,4,5,6,7,8,9] even in those patients who are at risk — the young, the old, and the seriously ill.

Prescribing Information *Presentation* Aqueous sterile solution of iopamidol. Niopam 200 contains 40.8% w/v (200mg iodine/ml). Niopam 300 contains 61.2% w/v (300mg iodine/ml). Niopam 370 contains 75.5% w/v (370mg iodine/ml). *Uses* X-ray contrast medium. *Dosage and administration* Myelography — Niopam 200. Adults 5-15ml, or 300. Adults 5-10ml; angiography — Niopam 300 or 370. Adults according to procedure;* iv urography — Niopam 300 or 370. Adults 40-80ml.* *Children according to body size and age. *Contra-indications* Hypersensitivity to iodine. *Precautions* Care in patients with history of allergy, severe functional impairment of liver, kidneys or myocardium, myelomatosis, epilepsy, diabetes, pulmonary hypertension, hyperthyroidism — especially patients treated for Graves' disease, pregnancy, and patients receiving neuroleptic or antidepressant therapy. Abnormalities of fluid and electrolyte balance should be corrected. During cardiac procedures ventricular arrhythmias may infrequently occur. Possible interference with thyroid function tests. *Side effects* As for similar non-ionic products. *Pharmaceutical precautions* Protect from light. Discard if solution is not clear of particulate matter. *Licence numbers* Niopam 200 — 5×10ml ampoule (0493/0065, PA 54/33/1); 5×20ml ampoule (PA 54/33/3). Niopam 300 — 5×10ml ampoule (0493/0066, PA 54/34/1); 5×20ml ampoule (PA 54/34/6); 50ml bottle (PA 54/34/3); 100ml bottle (PA 54/34/4). Niopam 370 — 5×10ml ampoule (0493/0067, PA 54/35/1); 5×20ml ampoule (PA 54/35/6); 50ml bottle (PA 53/35/3); 100ml bottle (PA 54/35/4); 200ml bottle (PA 54/35/7). 1. Fletcher EWL. *Br J Radiol* 1982, **55,** 36-38 2. Partridge JB *et al. Clin Rad.* 1981, **32,** 451-455 3. Molyneux AJ and Sheldon PWE. *Br J Radiol.* 1982, **55,** 117-119 4. Lea Thomas M and Briggs GM. *AJR.* 1982, **138,** 725-727 5. Macpherson P. *Br J Radiol.* 1982, **55,** 539-540 6. Corsi M *et al. Radiologia Medica* 1980, **60,** 215-218 7. Macpherson P and Teasdale E. *Br J Radiol.* 1982, **55,** 540-541 8. McAllister VL and Hall K. *Neuroradiology* 1983, **24,** 217-218 9. Drayer B *et al. Am J Neuroradiology* 1982, **3**(1), 59-64. Niopam is a trade mark.

BRACCO

MERCK E. Merck Ltd., Four Marks, Alton, Hants., GU34 5HG. Tel. 0420 64011

Dynaray-CH

Brown Boveri sets new standards: for example the DYNARAY-CH patient support unit.

Before we set about developing the treatment table for our linear accelerators, we had long discussions with the people who would have to work with it every day, i.e. with radiographers, treatment planners and therapists. The result is a table with features which fulfil all possible requirements not only now, but in the foreseeable future.

The advantages start already at the time of installation, because only a low-cost, 20 cm deep pit has to be built. Nevertheless the height of the table can be varied between 53 cm and 170 cm above the floor—the high-precision scissor design makes it possible. Also the extreme longitudinal movement of 160 (optionally even 190 cm) is not so easily matched. This range was chosen with dynamic therapy in mind. Actually, all therapy movements are firstly motorised and secondly prepared for a second verification channel, something which is essential for safe dynamic therapy.

The table movements are included in the accelerator's assisted set-up system. Simple operation of push-buttons enables the table top to be floated in the two main axes.

We don't just promise it—we have it!

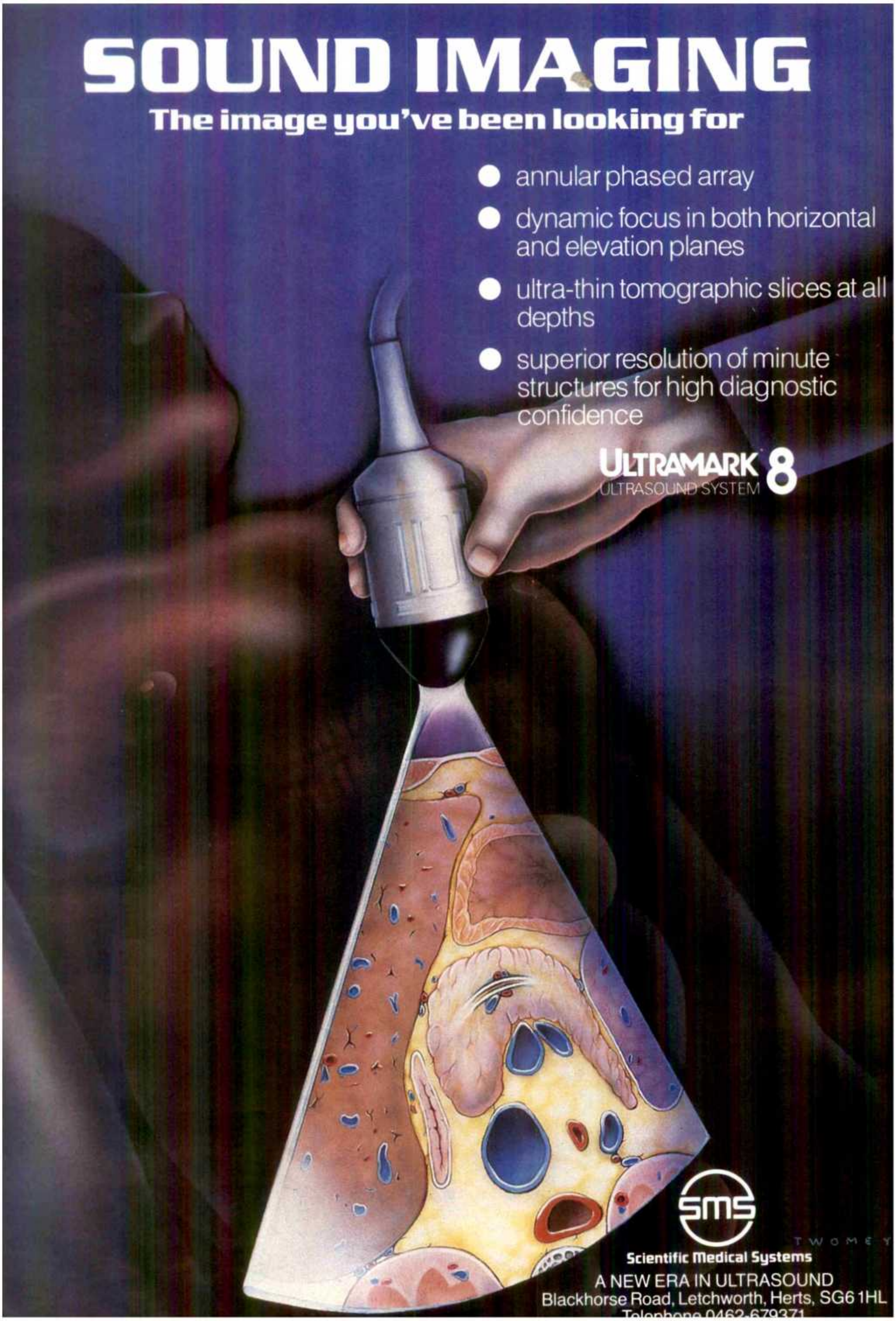
British Brown-Boveri Ltd.
Darby House, Lawn Central
Telford, Shropshire TF3 4JB
Telephone (0952) 502 000

or:

BBC Brown, Boveri & Company, Ltd.
Information Technology
CH-5401 Baden/Switzerland
Radiotherapy Department
Telephone 056/75 45 04 or 056/75 11 11

BBC
BROWN BOVERI

CH-IT 5024 87 E



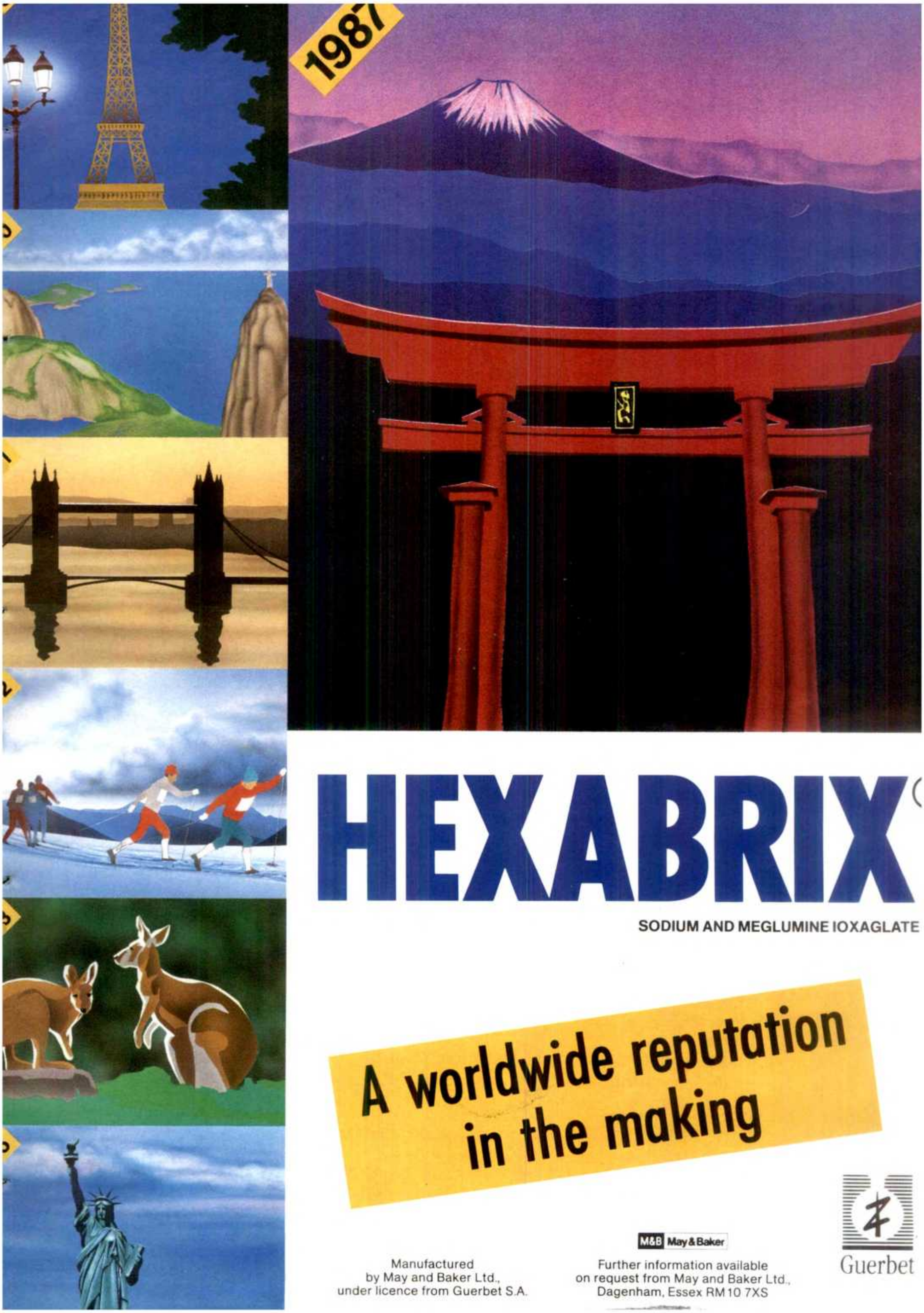
SOUND IMAGING

The image you've been looking for

- annular phased array
- dynamic focus in both horizontal and elevation planes
- ultra-thin tomographic slices at all depths
- superior resolution of minute structures for high diagnostic confidence

ULTRAMARK 8
ULTRASOUND SYSTEM

sms
Scientific Medical Systems
A NEW ERA IN ULTRASOUND
Blackhorse Road, Letchworth, Herts, SG6 1HL
Telephone 0462-679371



HEXABRIX

SODIUM AND MEGLUMINE IOXAGLATE

A worldwide reputation in the making

Manufactured
by May and Baker Ltd.,
under licence from Guerbet S.A.

M&B May & Baker

Further information available
on request from May and Baker Ltd.,
Dagenham, Essex RM10 7XS

Guerbet

TAKE THE HIGH ROAD
TO SCOTLAND

RADIOLOGY '88

23-25 May 1988 Glasgow

Britain's Open Forum
for all concerned with medical radiology
both diagnostic and therapeutic

STAR SPEAKERS
PROFFERED PAPERS
EXCITING SOCIAL PROGRAMME
MAJOR SCIENTIFIC POSTER EXHIBITION

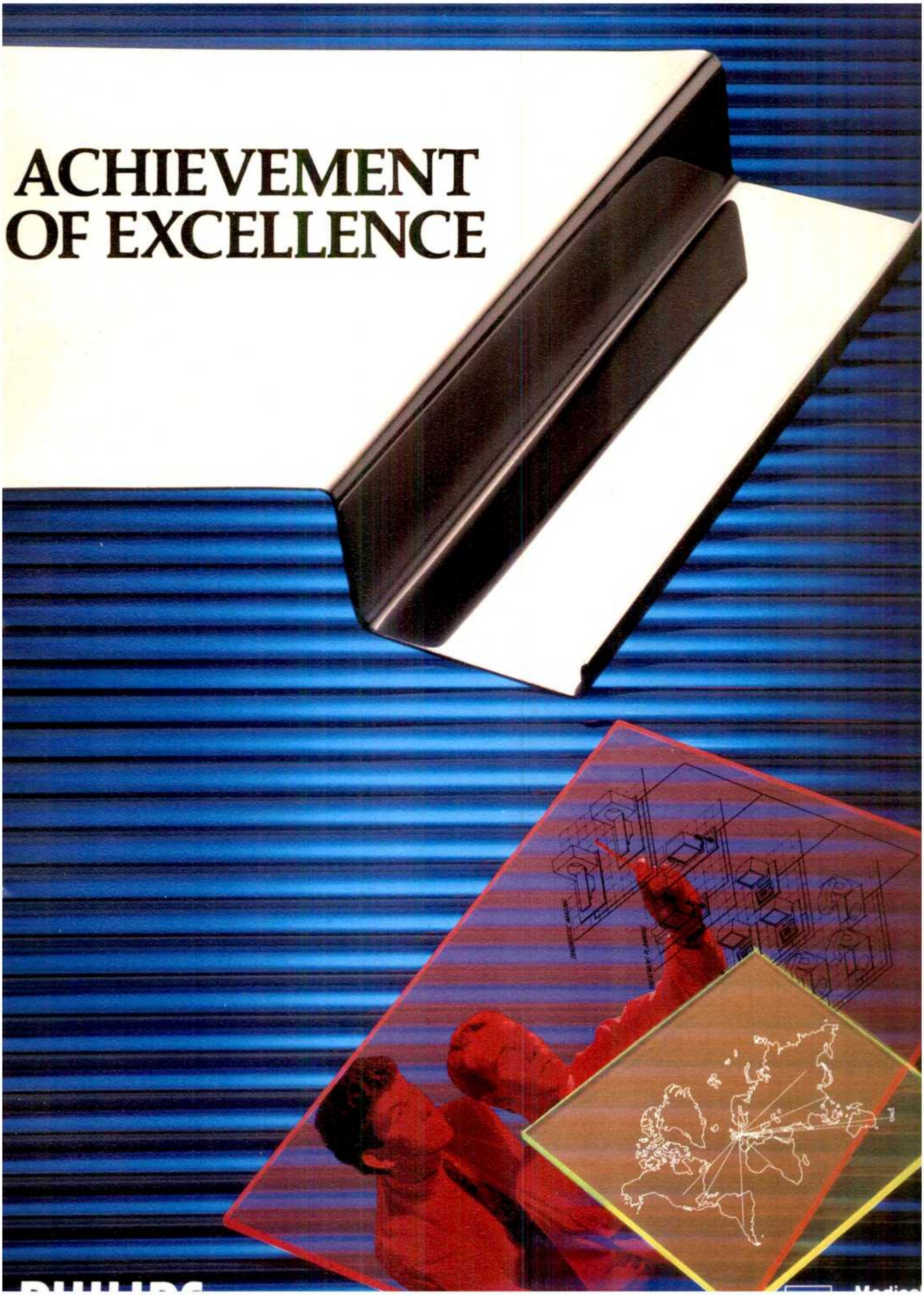
MED X RAY

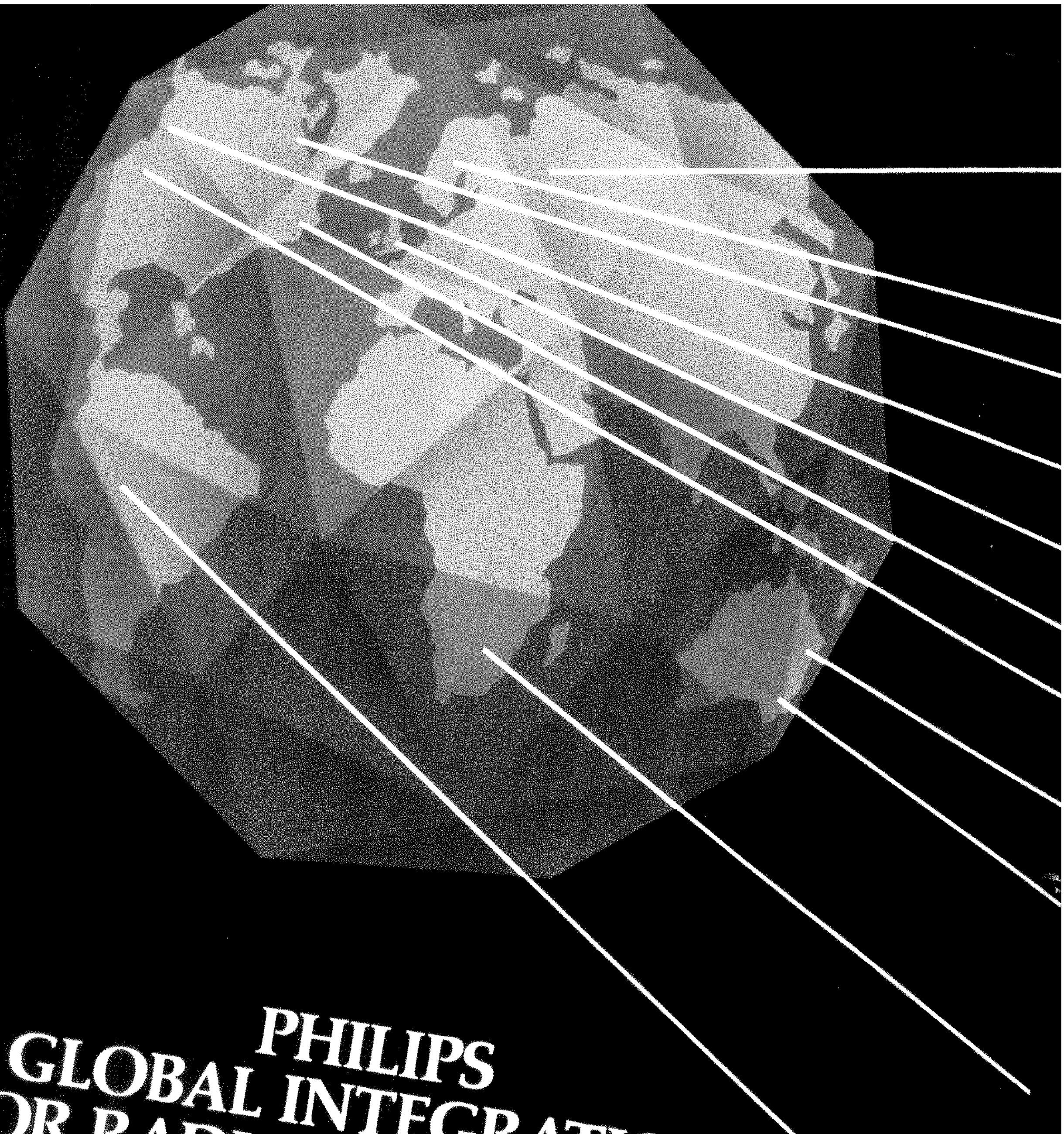
Britain's biggest radiological technical exhibition will span Radiology '88
and the annual conference of the College of Radiographers

RADIOLOGY '88
GLASGOW

Further information from
Conference Office
THE BRITISH INSTITUTE OF RADIOLOGY
36 Portland Place
London W1N 4AT
Telephone: 01-580 4085

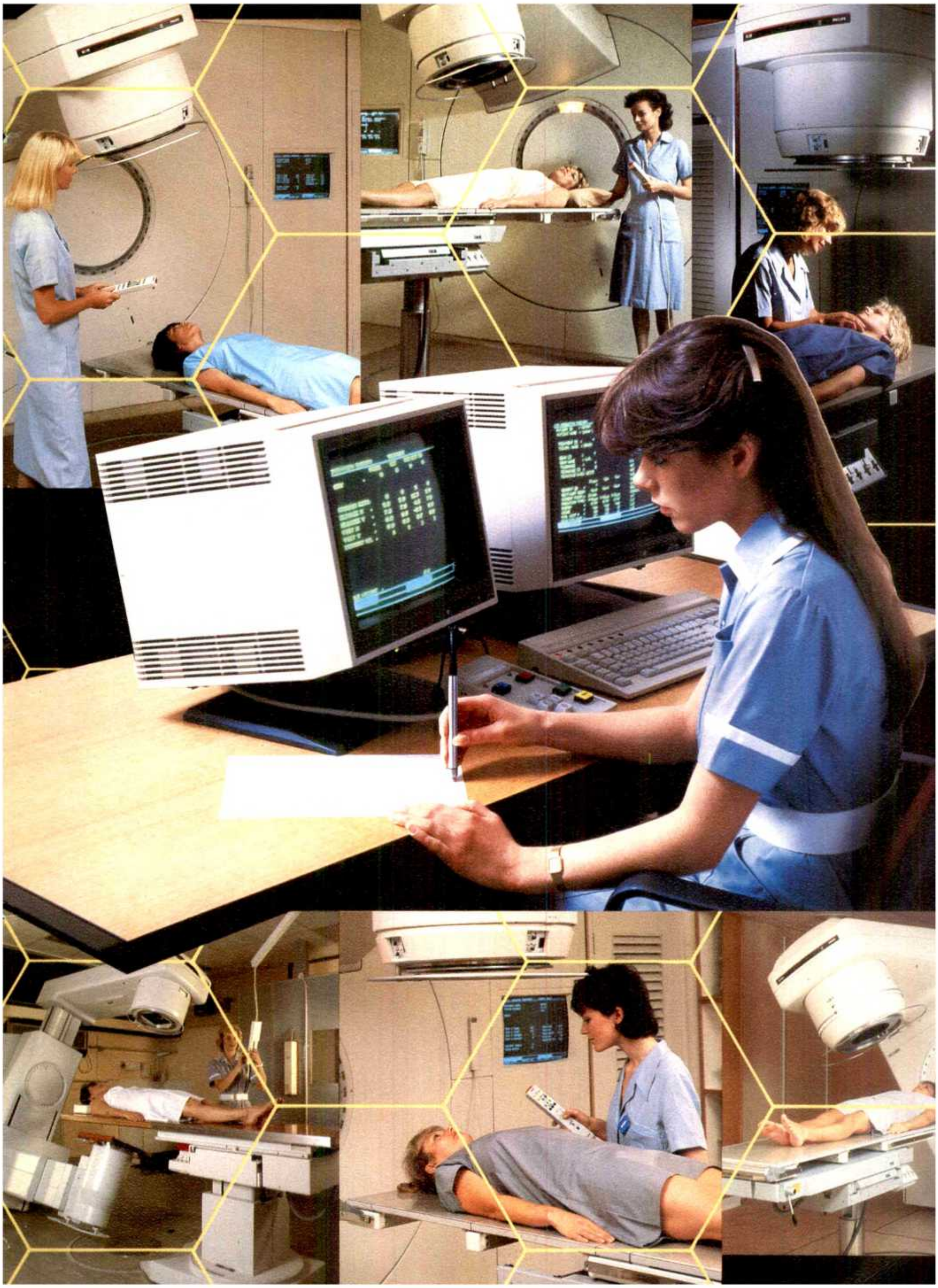
RADIOLOGY '88
GLASGOW

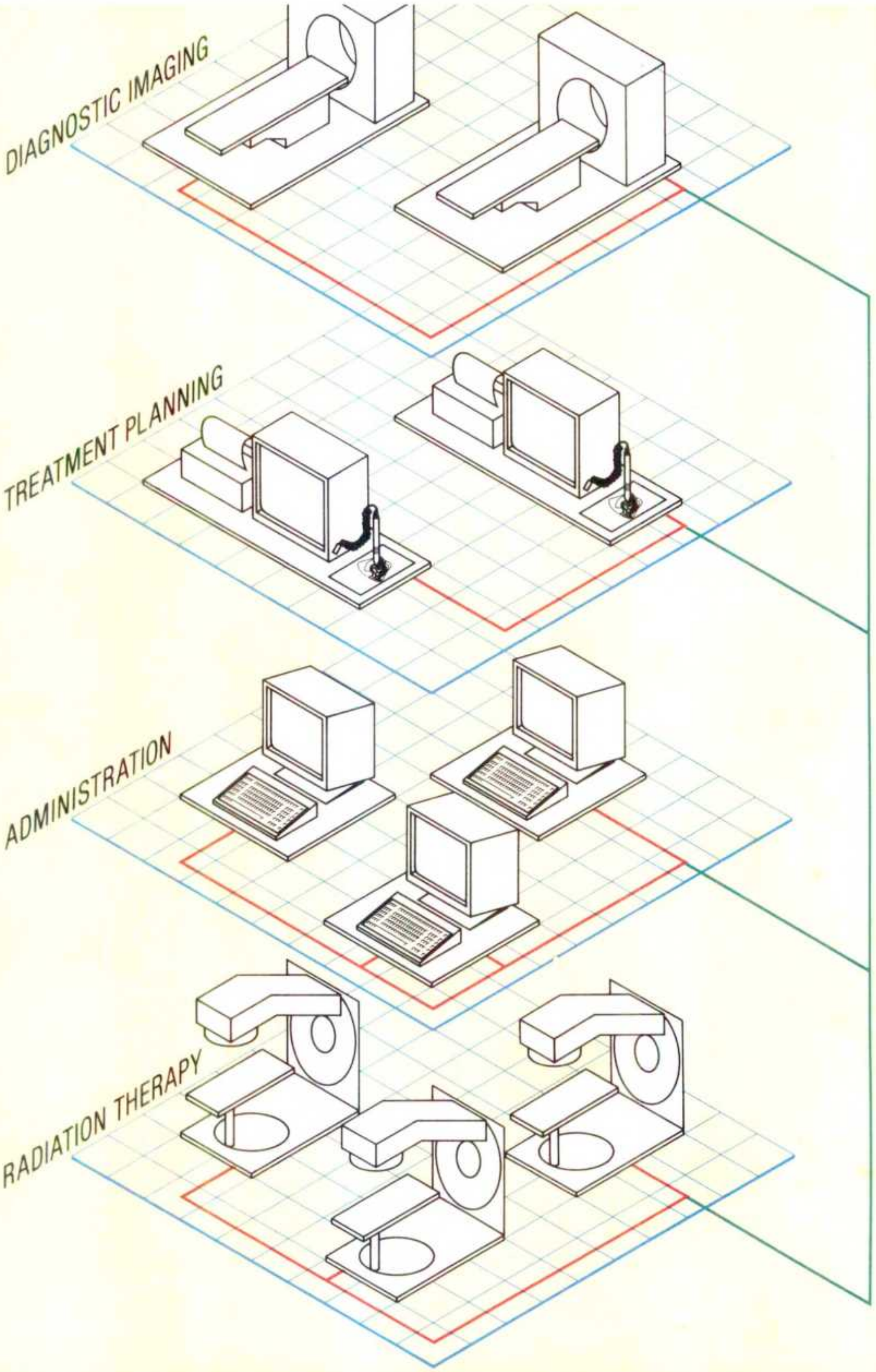

ACHIEVEMENT
OF EXCELLENCE



PHILIPS
GLOBAL INTEGRATION FOR RADIATION THERAPY

- ✻ Computer aided patient positioning
- ✻ Automatic data transfer
- ✻ High patient throughput
- ✻ Integrated range of compatible systems
- ✻ Networking for optimal data management
- ✻ Exceptional treatment versatility
- ✻ Remote service facility
- ✻ Minimum down time





Contact Philips at one of the addresses shown below
for more information on our full range of equipment for radiation therapy.

Philips Medical Systems, Kelvin House, 63/67 Glenthorne Road, Hammersmith, London W6 0LJ.
Philips Radiotherapy Division, Manor Royal, Crawley, Sussex RH10 2PZ,
Divisions of Philips Electronic & Associated Industries Ltd.

Philips Medical Systems Inc, 710 Bridgeport Avenue, Shelton, Connecticut 06484, United States of America.
N.V. Philips, Medical Systems Division, Eindhoven, The Netherlands.

Medica

PRINCESS MARGARET HOSPITAL
TORONTO, CANADA

CHIEF, DEPARTMENT OF IMAGING

The department is responsible for all professional radiologic and nuclear medicine services at the Princess Margaret Hospital, a provincial cancer hospital with 202 beds. The PMH has a service program in radiation and medical oncology with surgical consultation, and a teaching and research program in oncology. Over 7000 new patients with cancer are seen each year together with 165,000 ambulatory care visits. The hospital is in the process of rebuilding its facilities.

The chief should be an experienced physician/administrator with a strong commitment to clinical service, departmental administration, teaching and research. There are currently five professional members in diagnostic radiology, and one in nuclear medicine. Equipment includes CT, ultrasound, MRI.

Applicants should have certification in Diagnostic Radiology from the Royal College of Physicians & Surgeons (Canada) or equivalent, and demonstrated administrative skills as well as clinical. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. *For further details please write to:* Dr R S Bush, Director, Ontario Cancer Institute, 500 Sherbourne Street, Toronto, Canada M4X 1K9.

UNIVERSITY OF LONDON
British Postgraduate Medical Federation
THE CARDIOTHORACIC INSTITUTE
(in association with Brompton Hospital)

SEMINAR IN CHEST RADIOLOGY
27–29 January 1988

This course is designed for Registrars and Senior Registrars in training for the Fellowship of the Royal College of Radiologists. Topics will include:

- **Anatomy of the mediastinum**
- **Obstructive airways disease**
- **Pulmonary infections**
- **Opportunistic infections**
- **Pleural disease**
- **The lungs in systemic disease**
- **Chest trauma and intensive care**
- **Industrial lung disease**
- **Tumours of the lungs and mediastinum**
- **Neonatal chest radiology**

Group tutorials will be given

Course Organiser: Dr D Carr
Contributors: B Ayers, D Carr, C Flower, D Geddes, P Gishen, I Keer, K Levick, A Newman Taylor, M Pearson, M Phelan, S Rees, M Rubens, B Strickland and A Wilson.
Course Fee: £175
Application forms from: Postgraduate Course Secretary, Cardiothoracic Institute, Fulham Road, London SW3 6HP. Tel: 01-352 8121 Ext 8003

Medical Radiology

Diagnostic Imaging and Radiation Oncology

Edited by **L. W. Brady**, Philadelphia, PA;
M. W. Donner, Baltimore, MD; **H.-P. Heilmann**, Hamburg; **F. Heuck**, Stuttgart

The series recognizes the demand for an international state-of-the-art account of the developments reflecting the progress in the radiological sciences. Each volume conveys an overall picture of a topical theme so that it can be used as a reference work without taking recourse to other volumes. The contents of the volumes concentrate on new and accepted developments in a manner appropriate for review by physicians engaged in the practice of radiology.

H. R. Withers, University of California, Los Angeles;
L. J. Peters, University of Texas, Houston, (Eds.)

Innovations in Radiation Oncology

1987. 111 figures. Approx. 350 Pages. Hard cover. DM 236,-.
ISBN 3-540-17818-X

The book contains up-to-date reports on areas of growth in radiation oncology written for the practising radiation oncologist. Early chapters review conservative treatments that preserve the function and maintain or improve tumor control rates in breast, rectum, anus, head and neck, soft tissues and bones, and the eye. This is followed by a section dealing with extended field therapy encompassing total body irradiation, half body irradiation and systemic therapy with radionuclide-labeled antibodies. The potential roles of three new diagnostic imaging technologies (CT, MRI and PET) in radiotherapy are considered. Various modifications of treatment are reviewed, including hyperfractionation, accelerated treatment, accelerated hyperfractionaction and neutron therapy.

C. W. Scarantino (Ed.)

Lung Cancer

Diagnostic Procedures and Therapeutic Management
With Special Reference to Radiotherapy

1985. 42 figures. XI, 173 pages. Hard cover DM 120,-.
ISBN 3-540-13176-0

This up-to-date reference book covers a broad range of topics regarding lung cancer.
There is an extensive review of recent epidemiological and early detection studies, as well as of current histological observations of the tumor heterogeneity of lung cancer. It presents an up-to-date examination of the latest clinical developments in diagnosis and treatment as well as results of clinical trials employing irradiation chemotherapy and surgery.

Springer-Verlag
Berlin Heidelberg New York London Paris Tokyo
Heidelberger Platz 3, D-1000 Berlin 33
175 Fifth Ave., New York, NY 10010, USA
28, Lurke Street, Bedford MK40 3HU, England
26 rue des Carmes, F-75005 Paris
37-3, Hongo 3-chome, Bunkyo-ku, Tokyo 113, Japan

4091

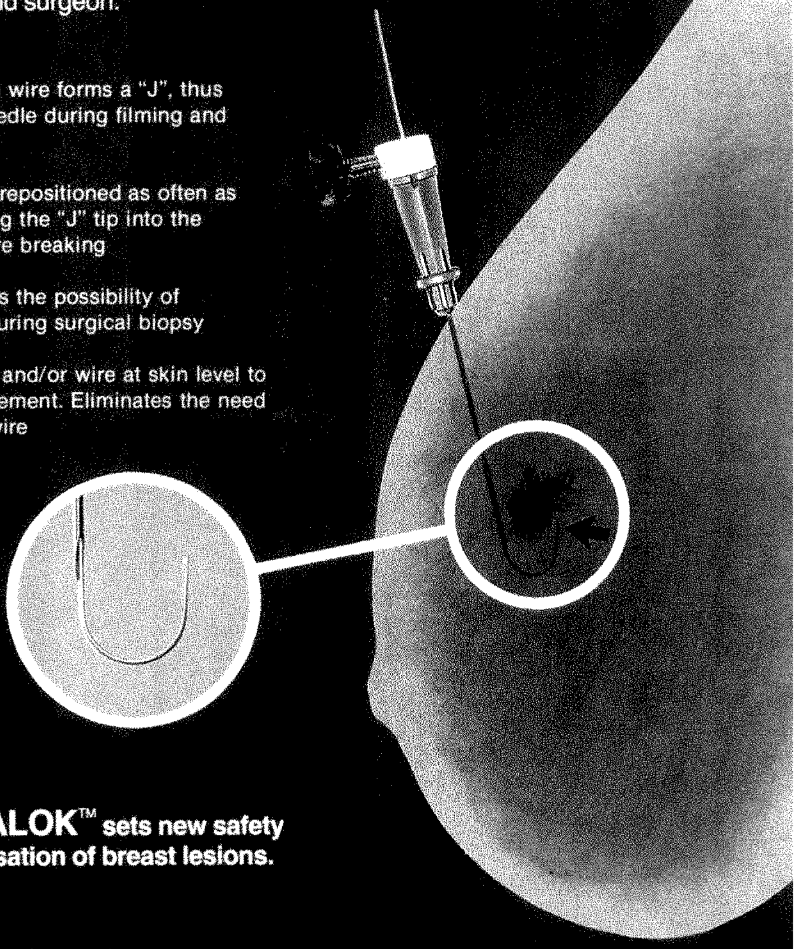
Springer

PRECISION WITH SAFETY

The NEW Namic® Mammalok™ Needle/Wire Localiser

A new and innovative system for localising non-palpable breast lesions which assures unprecedented SAFETY, ACCURACY and EASE OF USE for the radiologist and surgeon.

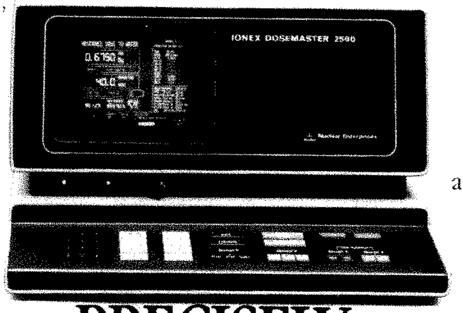
- When extended the localising wire forms a "J", thus immobilising the wire and needle during filming and patient transport
- The needle and wire may be repositioned as often as necessary by simply retracting the "J" tip into the needle without fear of the wire breaking
- A unique wire alloy eliminates the possibility of accidental wire transection during surgical biopsy
- Stabiliser secures the needle and/or wire at skin level to prevent migration or envelopement. Eliminates the need to tape down a long floppy wire
- Choice of three needle sizes — 1.5, 2.5 and 3.5 inches.



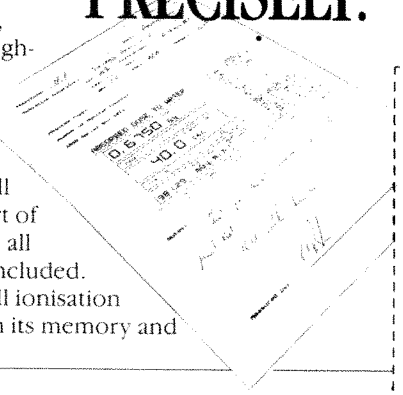
The NAMIC® MAMMALOK™ sets new safety standards for the localisation of breast lesions.

For further information contact:
X-RAY DIVISION
HENLEYS MEDICAL SUPPLIES
CLARENDON ROAD, LONDON N8 0DL
Tel: 01-889 3151

THE DOSE MANAGEMENT SYSTEM THAT PHYSICISTS CAN'T MANAGE WITHOUT.



PRECISELY.



The Ionex Dosemaster is what every Physicist has been looking for.

It is a more sophisticated and less laborious way to calibrate, monitor and record radiation dose.

As an all new and all embracing dose management system, the Dosemaster goes way beyond the capabilities of any ordinary dosemeter.

MORE FACTS AND FIGURES

Dosemaster comprises a visual display, dedicated function keys and a numeric keypad.

And for the physicist, it will fill its 9in. CRT screen with integrated dose, mean dose rate, elapsed time, all correction factors applied and calibration data. All this in large, clear numerals and with a choice of units – "R", "rad", "rem", "C/kg", "Gy" or "Sv".

Without prompting, the Dosemaster will highlight any out-of-limit parameters and will even double check its own readouts. And then, on request, it will print a complete report of the measurement with all relevant information included.

Dosemaster stores all ionisation chamber parameters in its memory and on entering the chamber serial number these parameters are brought into use. However, without knowledge of the password no changes or additions to the stored information are possible.

In short, it provides the means to calibrate and measure radiation, at all levels both accurately and quickly.

DUAL-CHANNEL MODEL

The two-channel model is ideal for ratio techniques and may also be used for two simultaneous and completely independent measurements.

So, if you are a medical physicist then get onto a good thing: get on the 'phone and ask us about the Dosemaster – NOW! Alternatively, use the coupon and we will send you full technical details.

Please send me full information about the 2590 Dosemaster

Name ____________________

Organisation ____________________

____

Address ____________________

____

____

BJR

NE TECHNOLOGY

N E Technology Limited
Bath Road, Beenham, Reading, Berkshire, England RG7 5PR
Telephone: (0734) 712121 Fax: (0734) 712835 Telex: 848475

In the USA: Nuclear Enterprises America
23 Madison Road, Fairfield, NJ 07006 Telephone: (201) 227-8215

ESSENTIAL BOOKS FOR RADIOLOGISTS FROM CHAPMAN AND HALL MEDICAL

DIAGNOSTIC IMAGING IN PAEDIATRICS

Edited by **I. Gordon**

The wide variety of images which can now be produced has made it necessary for the clinician to select the modalities appropriate to the clinical problem. The radiologist is increasingly aiding the clinician in this respect. The aim of this book is to give the paediatrician a logical step-by-step approach to the imaging of many clinical situations, and to illustrate the use of various imaging modalities including radiology, ultrasound, computerised tomography, and magnetic resonance.

November 1987 257 × 192 332pp
316 illustrations
Hardback: 0 412 22730 4 £57.50
Ex USA

RADIOLOGY OF ADVERSE REACTIONS TO DRUGS AND TOXIC HAZARDS

George Ansell

In recent years there has been an increasing awareness of the importance of adverse reactions to drugs, chemicals and other environmental hazards. This text indicates the valuable contribution of radiology to the diagnosis of these conditions and assesses the place of the newer imaging techniques. It provides a concise description of each topic together with literature reference to more detailed information.

The author is an acknowledged expert in this field and he has produced a comprehensive, well organised book. It is heavily illustrated, contains more than 1100 references and also includes a detailed index.

1985 400pp Hardback: 0 412 22140 3 £35.00

CHAPMAN AND HALL
11 New Fetter Lane, London EC3P 4EE

HEAD, DIVISION OF RADIATION ONCOLOGY TORONTO

The Toronto-Bayview Regional Cancer Centre and the Department of Oncology, Sunnybrook Medical Centre, University of Toronto, require a Head for a combined Division of Radiation Oncology. The Cancer Centre, an out-patient facility of the Ontario Cancer Treatment and Research Foundation, opened in 1981 and currently registers more than 3000 new patients annually. Rapid growth to 5000 new patients is anticipated. This growth will include a major facility expansion and a doubling in size of the current Division, which includes 11 radiation oncologists. Currently the in-patient operation is based on a 59 bed Oncology Unit.

This is a new position. The Division Head will be expected to have a strong academic record, be eligible for a Professorial appointment within the University of Toronto and be able to generate an important academic unit.

In accordance with Canadian Immigration policy preference will be given to a qualified Canadian applicant.

Further information may be obtained from: Dr. R.D.T. Jenkin, Director, Toronto-Bayview Regional Cancer Centre, 2075 Bayview Avenue, Toronto, Ontario M4N 3M5.

Al-Mutabagani Health Services Co. Ltd.

Fresh challenges, rewarding opportunities . . .
MHS has been successfully staffing and managing hospitals in the Kingdom of Saudi Arabia for the past 20 years. Confidence in the company's capabilities has again been emphasised by the award of the contract to recruit for and operate one of the newest and best equipped referral centres in the Kingdom.

Applications are invited for the posts of:

Chief of the Department of Radiology
10 years post Fellowship experience in diagnostic radiology required.

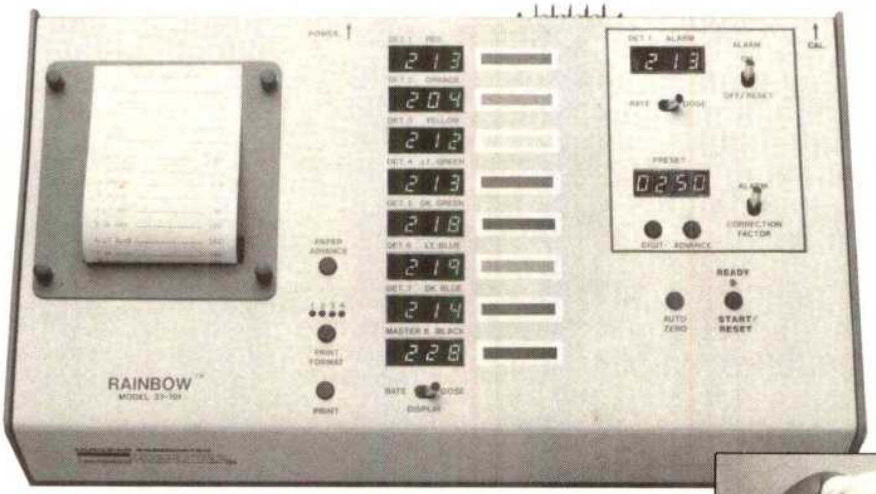
Consultant Radiologist
3 years post Fellowship experience including C.T. required.

Please send your resume to:

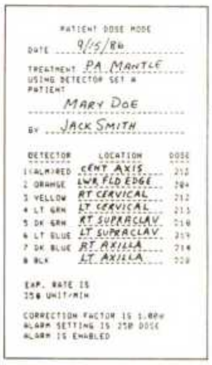
Eric Lyon, Arab Press House
182-184 High Holborn
London WC1V 7AP

Diode Dosimetry Systems

Patient Dose Verification and QA Beam Analyzer



8 DISPLAYS



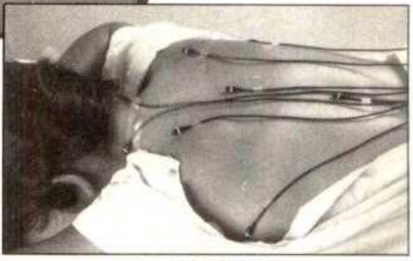
```
PATIENT DOSE MODE
DATE ...9/15/86..............
TREATMENT PA MANTLE.........
USING DETECTOR SET A
PATIENT
        MARY DOE
.............................
BY ...JACK SMITH.............

DETECTOR     LOCATION        DOSE
--------     --------        ----
1(ALM)RED   CENT AXIS....    213
2 ORANGE    LWR FLD EDGE.    204
3 YELLOW    RT CERVICAL..    212
4 LT GRN    LT CERVICAL..    213
5 DK GRN    RT SUPRACLAV.    218
6 LT BLUE   LT SUPRACLAV.    219
7 DK BLUE   RT AXILLA....    214
8 BLK       LT AXILLA....    228

EXP. RATE IS
350 UNIT/MIN

CORRECTION FACTOR IS 1.000
ALARM SETTING IS 250 DOSE
ALARM IS ENABLED
```

**PRINTED OUTPUT
FOR
PATIENT CHART**



8 DETECTORS

RAINBOW™

- Instantaneous Display of Treatment Dose
- Verifies Treatment Plans
- QA Checks of Beam Symmetry, Flatness and Energy

Instant Data on Exposure to Sensitive Organs During Treatment

DUAL DIODE DOSIMETRY SYSTEM

- Dual Channel Electrometer
- Rapid Checks of Equipment Output

For more details on Diode Dosimetry Systems, request Bulletin 3712-14

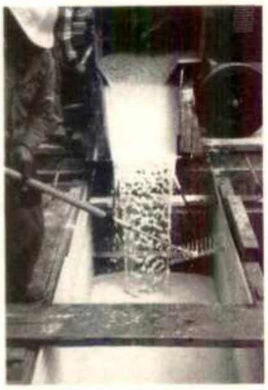
NUCLEAR ASSOCIATES

VICTOREEN

A Division of VICTOREEN, INC.
100 VOICE ROAD
CARLE PLACE, NY 11514-1593 U.S.A.
(516) 741-6360
A Subsidiary of Sheller-Globe SG

™ Victoreen, Inc.

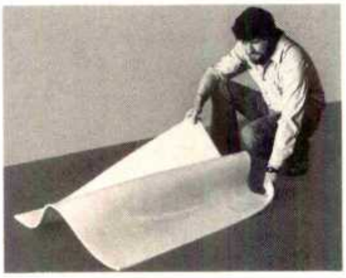
Shield Your Accelerator Room.



Installation of POLY/CAST in accelerator room roof for personnel protection

POLY/CAST

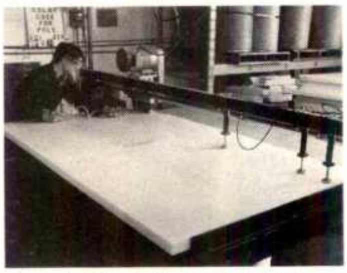
- Field-castable neutron shielding
- Used for walls and ceilings of accelerator installations
- Simple to use water-base mix



Borated FLEX/PANEL minimizes activation of concrete walls in treatment rooms

BORATED FLEX/PANEL

- Large, easy-to-install sheets. Flexible or rigid
- Used on walls and ceilings of treatment rooms to reduce capture gammas and minimize activation of concrete



Boron-loaded polyethylene for shielding against neutrons

BORON-LOADED POLYETHYLENE

- High Attenuation of Neutrons
- Used in hundreds of accelerator rooms

For further information contact:

REACTOR EXPERIMENTS, INC.
963 Terminal Way, San Carlos, CA 94070-3278
415/592-3355 • TELEX: 345505 (Reactex SCLS)

Our representative in the U.K.:

John Caunt Scientific, Ltd.
Oakfield Industrial Estate Eynsham, Oxford OX8 1JA Tel: Oxford (0865) 880479. Telex: 838852 JCS G

IN THE PRESS

A TEXTBOOK OF
RADIOLOGICAL DIAGNOSIS
5th Edition

(Formerly 'A Textbook of X-Ray Diagnosis')
Published under the auspices of the President and Council
of the Royal College of Radiologists

VOLUME 4
THE ALIMENTARY TRACT
THE HOLLOW ORGANS AND SALIVARY GLANDS
Ed. K. C. SIMPKINS, MB.BS, FRCP, FRCPE, FRCR, FRACR(Hon)
Consultant Radiologist, The General Infirmary at Leeds
754 pp. 1255 illustrations and 23 coloured plates.

H. K. LEWIS & CO. LTD
136 GOWER STREET, LONDON WC1E 6BS
Telephone 01-387-4282 Telex 22607

1987, *The British Journal of Radiology*, 60, 1049–1057

VOLUME 60 NUMBER 719 NOVEMBER 1987

The British Journal of Radiology

Seeing things more clearly*

By Gordon R. Higson

Department of Health and Social Security, 14 Russell Square, London WC1B 5EP

(*Received August 1986 and in revised form February 1987*)

Our Mackenzie Davidson Lecturer, Alex Margulis, recently described the last decade as "the golden era for developments in diagnostic imaging" (Margulis, 1985). In discussing some of the remarkable developments that have either originated or made their early progress in this country, I would argue that it was in the 1950s that the explosive development of medical imaging really began (Fig. 1).

In the Opening Address of the Annual Congress of the British Institute of Radiology in December 1953, V. W. Mayneord made "a case for physical resources to be applied increasingly to the investigation of the patient" (Mayneord, 1954); he pointed out the usefulness of the cathode-ray tube (CRT) for displaying radionuclide distributions and showed how radiography could be carried out with enormous reductions in dose by scanning the patient with a pencil beam of radiation. These concepts, and extensions of them, will be found to recur throughout my talk.

ULTRASONICS

In 1953, ultrasonic B-scanning had just been demonstrated. The probe was moved along a fixed path normal to the line of the beam so that a combination of probe position and echo time allowed the position of the reflecting surface to be determined. Coupling was by a water-bath. In 1955 Ian Donald and Tom Brown pioneered the use of compound B-scanning using a rocking probe in direct contact with the skin with oil or jelly as a coupling medium (Donald et al, 1958).

Manufacture of this equipment (the Diasonograph) was eventually undertaken by Nuclear Enterprises in the early 1960s. I have chosen the example of B-scanning as it appears to be the first instance of the Department of Health and Social Security supporting new imaging developments by purchasing four Diasonographs for trials in 1966.

Another very interesting ultrasonic imaging development which the Department assisted was the MAVIS (Mobile Artery and Vein Imaging System), developed by Peter Fish at King's College Hospital and GEC Medical between 1976 and 1982. MAVIS was a time-gated Doppler system for imaging blood vessels and measuring flow volume and velocity (Fish, 1975).

Despite the comprehensive information provided by this instrument, making angiography unnecessary in most cases, it was not a commercial success and is no longer on the market.

NUCLEAR MEDICINE

In 1953 radionuclide imagers were scanners in which a single, small detector was moved in a raster scan in a plane close to the patient. The Department supported at least two attempts to make the slow and clumsy scanner more useful. One was the development of the "Multipoise" scanner by the firm of J & P Engineering. This was a scanner with an elegant method of support for the scanning frame, which permitted its easy adjustment to any plane.

The other was a longitudinal tomographic section scanner developed at the Hammersmith Hospital between 1976 and 1978 (Myers & Tofts, 1978). The system worked satisfactorily but it was overtaken by gamma-camera developments and the greater ease of axial tomography.

Our most substantial and interesting investment in nuclear medicine was a failure. This was an attempt to design a semiconductor gamma camera of improved spatial and energy resolution inspired by the first Mayneord Lecturer, the late Roy Parker, and carried out at the Atomic Weapons Research Establishment in the late '60s. The basic detector unit was prepared from a slab of lithium-drifted germanium, about 5 cm square, by cutting a set of parallel grooves in each face of the slab. The two sets of grooves were orthogonal so that the combination of signals from rows and columns allowed the point of origin to be determined.

The system did all that was expected of it (McCready et al, 1971) but it was difficult to make uniform crystals. Also the need to maintain the detectors at liquid nitrogen temperature was seen as a great drawback and it proved impossible to find an industrial partner. This project, which was probably ahead of its time, was finally abandoned in 1973.

THERMOGRAPHY

The Atomic Weapons Research Establishment (AWRE) also began work in 1968 on behalf of the Department with the aim of developing a device able to produce images from infra-red radiation with a temperature resolution of 0.2°C and a spatial resolution of a few millimetres. The system is shown in Fig. 2. Radiant heat from the patient is reflected by a framing mirror oscillating once a second on to a drum rotating at 600 revolutions per minute and carrying 13 mirrors,

---

*The 1986 Mayneord Lecture, delivered in Bristol on April 9, 1986 at "Radiology '86".

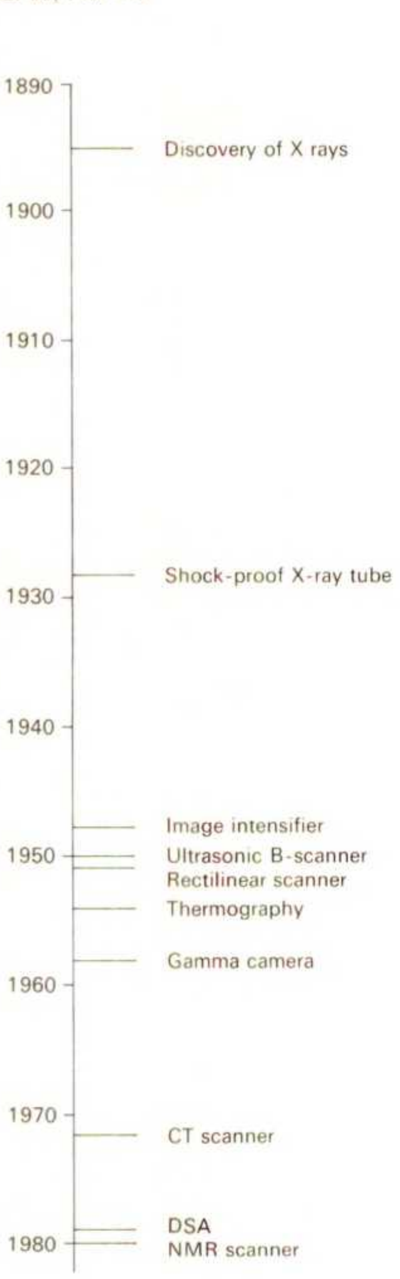


FIG. 1.

Timescale of major developments in medical imaging.

forming the line scan, then on to an indium antimonide detector. The detector is kept at 77 K and is calibrated at the end of each scan line when a reference oven is viewed (Watson et al, 1971).

The project was taken up by Barr and Stroud Ltd (now part of Pilkington Medical) in 1975 and several scanners produced by them were used in breast screening trials conducted in Bath, Edinburgh and Southend. This development cost some £200 000 between 1968 and 1978.

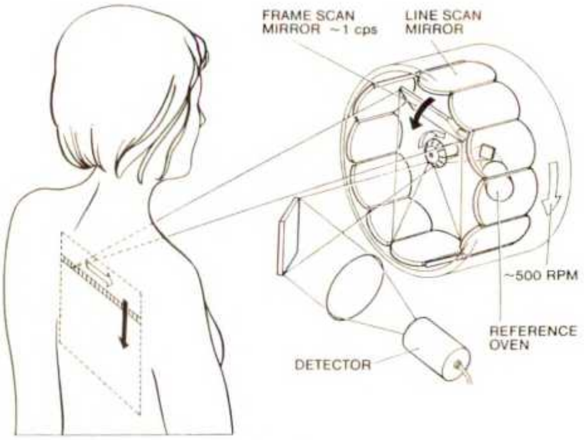


FIG. 2.

The AWRE thermographic camera (1971) (courtesy of AWRE).

COMPUTED TOMOGRAPHY

By far the most dramatic development in this period was computed tomography (CT). The Department of Health first became aware of CT scanning when Cliff Gregory was visited by Godfrey Hounsfield of EMI during 1968 and was introduced to Hounsfield's ideas for obtaining sectional pictures of the body by the use of a narrow beam of X rays.

In January 1969, Gregory, myself and Dr Evan Lennon, a radiologist who was at that time on the staff of the Department, visited the EMI Laboratories at Hayes to discuss the scheme and see Hounsfield's equipment in action. At that time it consisted of a gamma-ray source and a Geiger tube detector, both fixed, and an old machine tool indexing table on which the specimen was mounted. This equipment, which took 2 days to examine a specimen, is shown in Fig. 3 and is

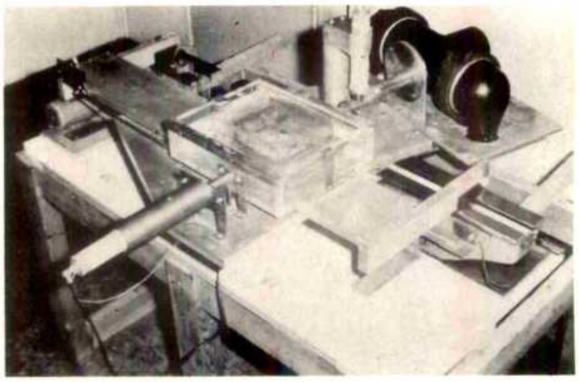


FIG. 3.

Equipment used by Sir Godfrey Hounsfield in 1969 to demonstrate the feasibility of computed tomography. (Courtesy of Thorn-EMI.)

now on display in the museum at EMI's Central Research Laboratory.

The feasibility study on which we agreed to share costs with EMI was aimed at developing this equipment into a form in which biological specimens could be examined. This involved changing to the use of an X-ray source in place of the monoenergetic gamma-ray source and the use of a CRT for picture display.

The feasibility study was successful and we then invited three radiologists to carry out a critical examination of this system by submitting a variety of specimens for examination on Hounsfield's rig and verifying the resulting photographs by sectioning the specimens and comparing what was seen with what was shown on the scans. We invited Dr James Ambrose (Atkinson Morley's Hospital), Dr (now Professor) Frank Doyle (Hammersmith) and Dr Louis Kreel (then Northwick Park) to take part in these tests and we agreed with EMI to share the costs on a 50–50 basis. The detector readings were recorded on punched paper tape which then had to be taken to the big EMI computer for processing. This produced yet another paper tape which was used to control the CRT display. Nevertheless, even then the pictures were being calculated and displayed on an 80 × 80 matrix with absorption coefficient accuracies of about 2–3%.

In January 1970 the three radiologists gave us their conclusions. They were very enthusiastic about the possibilities of the new system and urged us and EMI to get equipment into clinical use as soon as possible (Kreel, 1977).

In February 1970 the provisional specification for a clinical prototype was submitted by Hounsfield and was worked up into its final form over the next 3 months or so. The scanning time for a slice 1 cm thick was estimated as 4 min and the decision was made to design the first prototype specifically for brain scanning. There was no thought at that time of having a computer integral with the scanner.

EMI sought the advice of a team with a hospital experience to review their design work on the prototype. It consisted of: Evan Lennon, the late Owen McCabe, and myself (later Norman Slark) from the Department; Brian Keane, a hospital physicist from Royal Sussex County Hospital; Dr James Ambrose from Atkinson Morley's Hospital, which had been chosen as the home for the prototype; and, of course, Godfrey Hounsfield and various members of his design team as it grew over the ensuing months.

This key advisory team met every month from September 1970 until August 1971. It was not just another committee but was a working team which spent a large part of its time in EMI's drawing office and laboratory and there is no doubt in my mind that its infusion of practical hospital experience into the design process was a major factor in the success of the prototype.

At that time the total market in the UK was thought to be about 12 scanners and EMI were already looking to the USA for most of their sales. The prototype was installed in Atkinson Morley's Hospital in September 1971 and in October 1971 the first clinical pictures were taken (Fig. 4). In February 1972 we received a report from Dr Ambrose which described the scanner as successful and we were able to confirm our intention to buy two more.

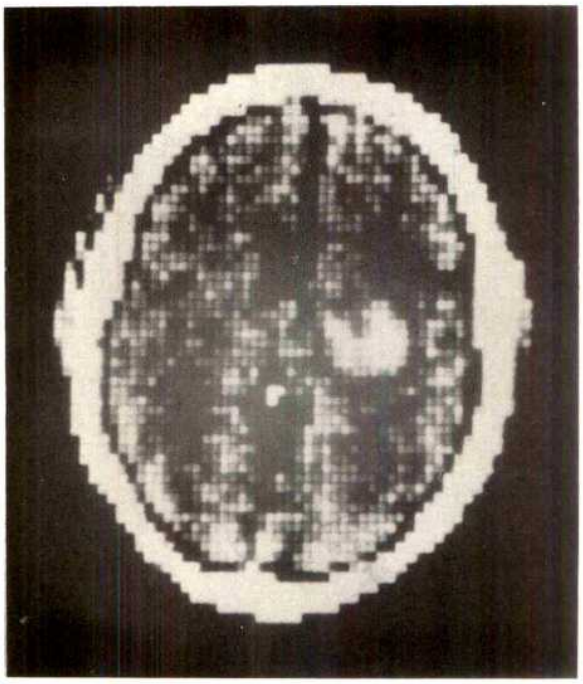


FIG. 4.

Early Emiscanner image showing brain tumour. Atkinson Morley's Hospital, 1971, 80 × 80 matrix.

In April 1972 Godfrey Hounsfield and James Ambrose described the EMI scanner and the first results to an excited audience at the Annual Congress of the British Institute of Radiology (Ambrose & Hounsfield, 1973). Computed tomography received immediate acclaim. The new information provided by these images, of a sort that had previously been seen only in the pages of anatomy textbooks, was eagerly welcomed and the virtual elimination of ventriculography, angiography and nuclear medicine techniques in favour of simple outpatient examinations made formal cost–benefit analysis virtually superfluous.

Hounsfield was appointed to the Fellowship of the Royal Society in 1975, was awarded the Nobel Prize for Medicine in 1979 and was knighted in 1981.

Up to the building of the first four scanners, the development was jointly funded by the Department and EMI. Our contribution came to about £½ M, but from then on the project was self-funding and the Department received a handsome return in the form of royalties. The first whole-body scanning prototype was

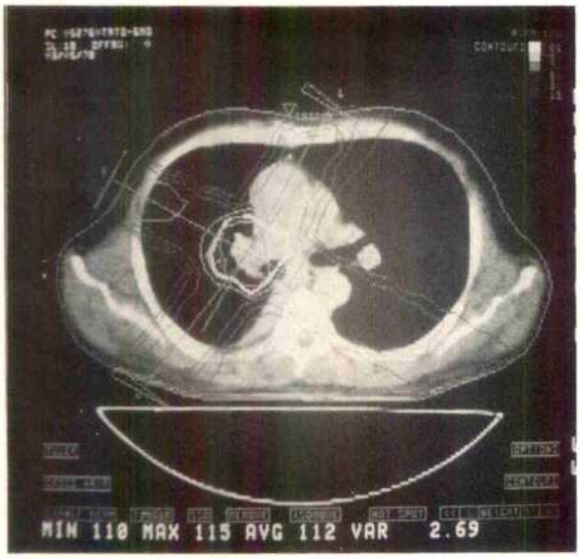


FIG. 5.

Radiotherapy treatment planning system; isodose distribution superimposed on CT image (*c*. 1980). (Courtesy of IGENY.)

developed by EMI at their own expense but our support continued in the form of the provision of evaluation facilities at Northwick Park Hospital where its use was explored by Louis Kreel, at a cost to us of about £¼ M (Brownlie & Kreel, 1978).

Our next real involvement was not until 1978, by which time EMI had acquired the rights to the radiotherapy treatment planning system originally developed at the Royal Marsden Hospital and known as the Rad-8. The potential of linking CT images and treatment planning was appreciated by the EMI researchers and a development programme carried out in conjunction with the Royal Marsden was funded by EMI, ourselves and the Cancer Research Campaign, our share being £150 000. The results of this exercise were described by the late Roy Parker in the first Mayneord Lecture (Parker, 1984) and an example is shown in Fig. 5.

The resulting treatment planning system, capable of exploiting the morphological and tissue density information provided by the CT scanner, has been further developed to permit three-dimensional planning and is now manufactured by IGE Ltd at Radlett.

NUCLEAR MAGNETIC RESONANCE

During the 1970s, another imaging modality moved gradually into view: nuclear magnetic resonance, a term now replaced by magnetic resonance imaging (MRI). In 1978 EMI published the first MRI image of a living human head (Fig. 6), made at their Central Research Laboratories on a laboratory system which took 12 min to scan and used back-projection reconstruction (Clow & Young, 1978).

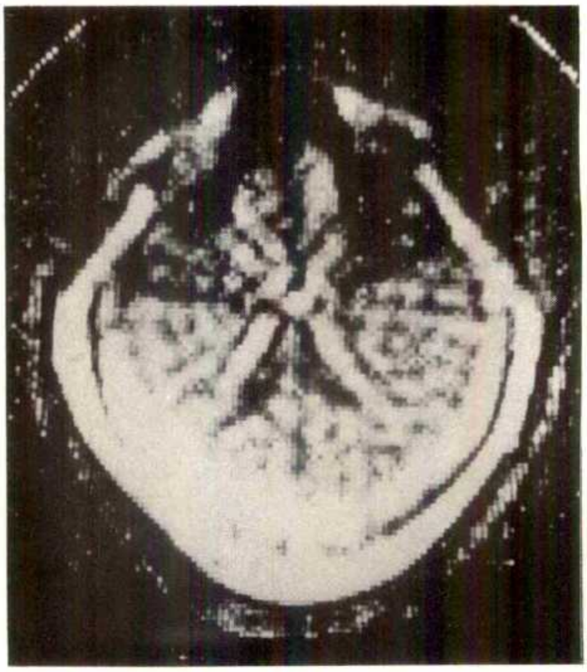


FIG. 6.

First NMR head scan, 1978 (courtesy of *New Scientist*).

By late 1978 we had decided to go in with EMI in the development of a clinical prototype and to contribute £350 000 on a cost-sharing basis and had nominated the Royal Postgraduate Medical School as clinical collaborators. Estimates then were that EMI might sell 20 machines a year at £¾ M each.

Early in 1979 it was decided to use a cryogenic magnet made by Oxford Instruments. The production of this magnet was a development project in itself to meet requirements of a peak field of 0.3 T and uniformity of 10 parts per million over a 14 cm radius. The project team, consisting of the EMI team, led by Ian Young, Hammersmith personnel and ourselves met for the first time under John Williams' chairmanship in April 1979 (very similar in make up and function to the CT scanner project team 10 years earlier) and had agreed a target specification for "Neptune" by June 1979.

The question of the safety of the patient exposed to radio-frequency radiation and rapidly changing magnetic fields was referred to the National Radiological Protection Board (NRPB) who reported early in 1981, before any patients were scanned (NRPB, 1981).

The building was completed in November 1980 and the Neptune was moved in there in January 1981. The first images were produced in February 1981.

In 1980 Thorn-EMI had sold the CT business to General Electric of the USA, who still make medical equipment in the Radlett factory, and the Neptune project to Picker International Ltd. This was the new

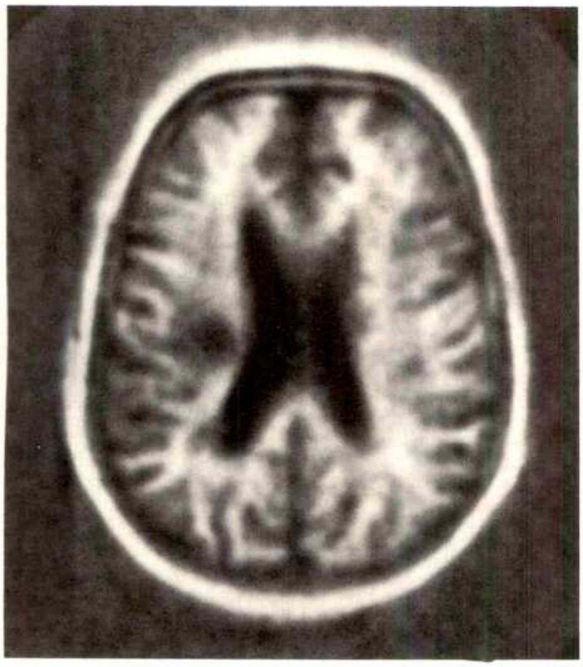


FIG. 7.

Early NMR demonstration of multiple sclerosis at RPMS, Hammersmith (1981).

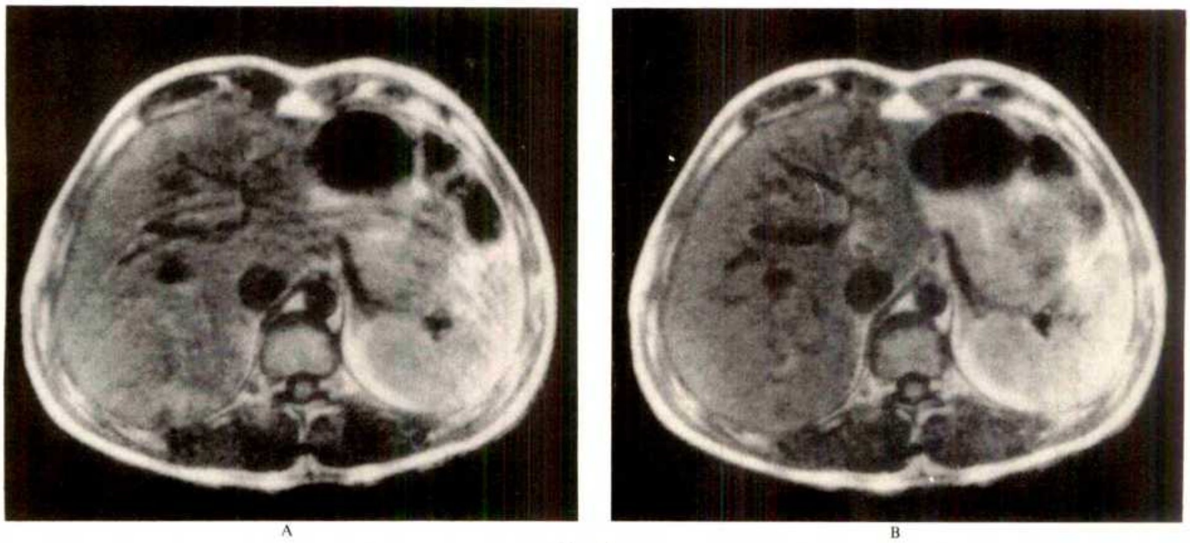
name for the old GEC Medical company and resulted from GEC's acquisition of the American Picker Company shortly beforehand.

Then began an intensive period of exploring the usefulness of MRI under the direction of Robert Steiner. The first, and perhaps still the most important, uses were found in examination of the brain because of the ability to distinguish grey and white matter (Fig. 7) and to image the posterior fossa. The Neptune has also been used as a testbed to explore new techniques: the use of surface coils (Bydder et al, 1985), the ROPE (respiratory organised phase encoding) process for reducing breathing artefacts (Bailes et al, 1985) (Fig. 8) and the use of gadolinium chelates as contrast media (Bydder et al, 1984).

During the same period we also supported the clinical exploration of MRI at the Queen's Medical Centre, Nottingham. This began in the pre-Picker days when GEC Medical were interested in taking up the resistive scanner developed at Nottingham University (Holland et al, 1980). A unit built at the University for GEC was bought by us and installed in Brian Worthington's department. In mid-1984 we replaced this prototype unit with a production Picker resistive scanner of 0.15 T field strength with which Brian Worthington has been able to confirm that clinically useful imaging can be carried out at low field strengths (Fig. 9).

Also at Nottingham we have supported Professor Peter Mansfield in taking his echo-planar imaging technique to a practical stage. He has demonstrated the ability to produce 64 × 64 images in 16 ms and even real-time movie images (Ordidge et al, 1982). We are hoping to see echo-planar imaging commercially available within the next two years.

Our expenditure of taxpayers' money on the development and evaluation of MRI has so far reached £3¼ M over seven years—equivalent to well over £4 M in today's money.



A

B

FIG. 8.

An NMR abdominal image (A) normal, (B) using the ROPE technique to reduce breathing movement artefacts (spin-echo, 256 × 256, 1985).

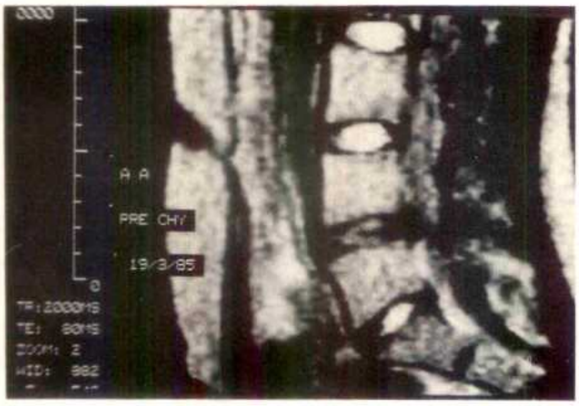


FIG. 9.

An NMR image of the spine. Normal discs show a white nucleus but the L4–L5 disc shows loss of signal from the nucleus and posterior protrusion (spin-echo, 128 × 128, 1985).

PERFORMANCE MEASUREMENT

I now want to turn to another aspect of seeing things more clearly. To do this, we must have readily available methods of measuring the performance of imaging systems. These are needed for two purposes: to help users choose the best equipment for their needs, and to help maintain equipment performance at an optimum level.

Providing advice to the National Health Service (NHS) on the relative merits of competing equipment is a major occupation of the DHSS Scientific and Technical Branch. This activity has grown dramatically since about 1975 and today we spend about £2 M per year on the evaluation of medical equipment of all kinds and about half of it on imaging equipment.

Ultrasonics

In 1969 we asked AWRE to test the performance of several ultrasonic A-scanners and subsequently a range of B-scanners. Several novel and useful test methods were developed by AWRE, but unfortunately they are described only in an internal report (Montgomery, 1972). These two test series were reported in HEI Nos 34 (DHSS, 1971) and 57 (DHSS, 1975). Later evaluations of ultrasonic imaging equipment have been carried out in Scotland, with financial support from the Scottish Home and Health Department and are reported in HEI 81 (DHSS, 1979) and 84 (DHSS, 1980a).

The methods used in these evaluations are not suitable for routine performance checks but work supported by us at Surrey University and University College of Wales (Cardiff) has resulted in the development of gels with acoustic transmission properties similar to those of tissue. Test objects composed of reflecting surfaces embedded in these gels are now commercially available (Diagnostic Sonar Ltd) and are useful for keeping B-scanners, linear arrays and phased-array scanners up to the mark (McCarty & Stewart, 1982).

Radiology

Our most extensive and most costly evaluation activity is in the field of conventional X-ray equipment where the building and running of the King's Centre for the Assessment of Radiological Equipment (KCARE) has cost about £2¼ M to date (Hancock, 1981). It is always necessary to ask whether this expenditure is worthwhile and in doing so it must be put in perspective by remembering that the NHS has spent something like £200 M on conventional X-ray equipment in the same period.

Although the suggestion that the DHSS should set up an evaluation centre for X-ray equipment was made in 1971, the building did not begin until March 1978. It was completed on June 30, 1979 at a cost of £300 000. Colin Hancock was appointed Project Co-ordinator in March 1979, and up to now 65 reports have been issued.

In 1972 we began to support George Hay and Fred Clarke at Leeds on research into methods of measuring the performance of image intensifier/TV systems. By 1976 a set of test objects had been developed which enabled the measurement of noise and contrast loss, modulation transfer function (unsharpness) and intensity transfer function (grey scale). The Department then decided to ask the team at Leeds to carry out a programme of evaluation of commercially available image intensifier/TV systems. Since then, the name of FAXIL (Facility for the Assessment of X-ray Imaging Leeds) has been adopted and 25 reports published.

Besides the test equipment and objects developed for the evaluation programme, the Leeds team has succeeded in producing phantoms for use in the hospital for checking fluoroscopy systems (Hay et al, 1985). Used in conjunction with the Model 633 Dose Monitor, developed at AWRE and now available from Vinten Ltd, the Leeds test objects (available from Leeds University) can be used by any radiology department to keep their fluoroscopic equipment in good order (Fig. 10). This entire programme has cost some £350 000.

Nuclear medicine

The Hospital Physicists' Association (HPA) published guidance on the testing of gamma cameras in 1978 (HPA, 1978), and in 1979 the Department commissioned St Bartholomew's and University College Hospital to establish a programme for the evaluation of gamma cameras. Equipment has been designed to allow the measurement of intrinsic resolution, system resolution, non-uniformity, spatial distortion, sensitivity, count-rate performance, energy resolution and shield penetration. Three reports have been published so far, in 1980 (DHSS, 1980b), 1982 (DHSS, 1982) and 1985 (DHSS, 1985). The next one will be published in the near future. This programme has cost £57 000 so far.

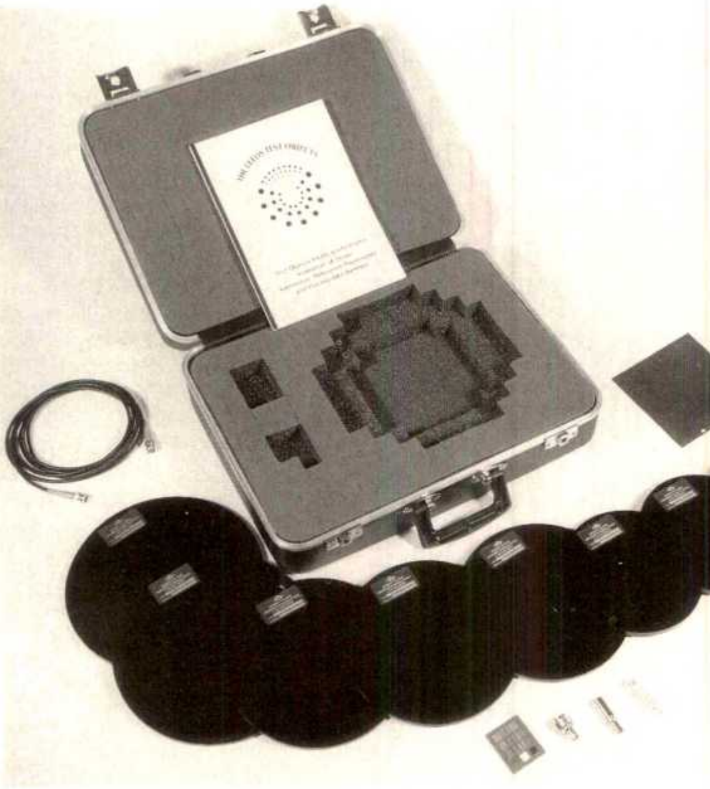


FIG. 10.

Set of Leeds test objects. With this easily carried set it is possible to analyse completely a fluoroscopy system.

Computed tomography and magnetic resonance imaging

The evaluation of really new devices sets problems for the evaluators. It might be worth mentioning that the acceptance test for the first Emiscanner prototype was a comparison of scans of a test specimen on both the clinical prototype and the laboratory equipment. Obviously we needed to improve on this and we gathered together a group of physicists to design phantoms for acceptance and quality assurance testing. This progressed to phantoms for the evaluation of different scanners now used on our behalf by John Perry's Department at St George's Hospital to enable us to give advice to anyone thinking of buying a CT scanner. We have spent £53 000 on this service so far and examined 26 scanners.

Today we face the same problems with magnetic resonance imagers and the Medical Research Council (MRC)/DHSS Co-ordinating Committee on the Evaluation of MRI has set up a technical subcommittee under the chairmanship of Stewart Orr to develop test methods with financial support from DHSS.

THE FUTURE

I am not going to try today to make predictions about the future of imaging but a number of developments can be identified already. We are already supporting work on faster methods of MRI, on imaging in non-uniform magnetic fields, and on other developments aimed at making MRI faster, cheaper and more widely applicable. I expect MRI to progress in the next decade in the same way as CT scanners during their first 10 years.

Figure 11 shows that, in real terms, a CT scanner is no more expensive today than it was in 1974 but in 1974 it took 4 min to do a scan, the patient was enveloped in a water bag, and the images were

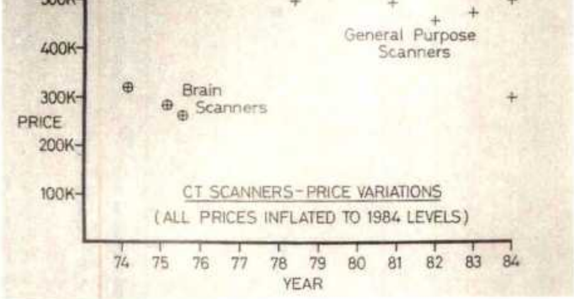


FIG. 11.

Ten-year variation in prices of CT scanner normalised to 1984 values.

presented on a 80 × 80 matrix. Today a scanner needs no coupling, scans in only a few seconds and is likely to offer a 512 × 512 matrix display with magnification. In the light of this experience, what will be the cost and performance of an MRI scanner in 1996?

I also look forward to improvements in MRI scanners, or in techniques and phantoms that will permit their calibration, that will allow the quantitative information in the MRI image, particularly the values of the T_1 and T_2 relaxation times, to become more useful in diagnosis. The process might be stimulated by the linking of magnetic resonance imaging and spectroscopy. We have contributed some £¼ M towards the provision of magnetic resonance spectroscopy equipment used by George Radda at Oxford. Unfortunately, his research has not been associated with MRI, but within the next year we hope to establish at Hammersmith, in partnership with the MRC and Picker International, a major centre for the study of magnetic resonance in medicine which will have spectroscopy as well as imaging facilities.

I hope that this centre will establish how quantitative information can be added to imaging in order to increase its value. It may also answer the question posed by Mayneord in his closing remarks at the Mayneord Symposium in 1982 (Mayneord, 1982):

> Nowadays the air is filled with images which certainly give delight to those producing them and, we hope, hurt not the patients. The images may be produced by a wide range of agents . . . . Often we seem not to know at all clearly what we are forming an image of! Something to do with the tissue doubtless—but what?

Many of you who attended last year's Annual Congress will be aware that for some years we have been studying the design of a hospital in which all diagnostic images would be stored in digital form, transmitted in either digital or video form and displayed on a CRT. Such a hospital demands a high capital investment but offers possibilities of more economical and efficient running of the radiology department, and of the hospital. It will allow the diagnostician to compare in rapid succession the images from different examinations, such as radiography, nuclear medicine and ultrasound. Other diagnostic benefits are expected to accrue from the use of image enhancement and manipulation techniques, familiar from CT and MRI, on conventional X-ray images. It is also hoped that the image will never get lost in such a system!

We have spent £¼ M on the feasibility study and design study of such a system and these are available to any health authority seriously considering installing one. We did intend to install it in the new St Mary's Hospital but failed to find the funds to do so. This was the big disappointment of last year, but our interest in installing and evaluating a filmless radiology department, and ultimately a filmless hospital, has not gone away and we will surely be involved in this adventure in the near future.

In this talk I have attempted to pay tribute to the foresight of Val Mayneord, to celebrate the inventiveness of British scientists, and to give some account of what we, in the Department, do with your money. Table I shows how we have distributed the money available to us in the last 10 years on research and development of new medical equipment of all kinds.

I think the results that I have described make the point that the co-operation that is possible in this country between industrialists and the NHS, aided by a sympathetic Government department, have kept the United Kingdom in the forefront of medical imaging research and development. I hope this progress will continue in the future and that we will add to it increasing commercial success.

It has been a great honour for me to give this lecture which bears the name of such a distinguished medical physicist as Val Mayneord. I believe that the invitation to give it was a rare tribute to the work of my Department and that many of my colleagues will share my pleasure in it.

I owe my thanks to a large number of these colleagues and will mention particularly Norman Slark, John Williams, Colin Hancock, Colin Robertson and Ken Barnes. I am also grateful to the many distinguished workers whose names have been mentioned for the provision of slides and tapes.

Any opinions expressed in this talk are mine and not those of the DHSS.

TABLE I

THE DHSS SPEND ON RESEARCH AND DEVELOPMENT BY SUBJECT AREA, 1975–86

	%	£ × 1000
NMR	11.0	2104
Other imaging	11.4	2159
Radiotherapy	5.1	975
Electromedical: patient monitoring	11.7	2232
Life support	11.5	2196
Organ preservation	0.03	6
Enzymes, vaccines etc.	7.1	1361
Dental materials	5.4	1024
Medical optics	3.2	605
Invalid transport	2.4	449
Aids for the disabled	15.2	2906
Hearing aids and environmental aids	2.6	500
Not classified	10.1	1941
Total	100	19093

REFERENCES

Ambrose, J. & Hounsfield, G. N., 1973. Computed transverse axial tomography. *British Journal of Radiology, 46*, 148–149.

Bailes, D. R., Gilderdale, D. J., Bydder, G. M. , Collins, A. G. & Figmin, D. N., 1985. Respiratory ordered phase encoding (ROPE); a method for reducing respiratory motion artefacts in magnetic resonance imaging. *Journal of Computer Assisted Tomography, 9*, 835–838.

BROWNLIE, K. & KREEL, L., 1978. Computer assisted tomography of normal suprarenal glands. *Journal of Computer Assisted Tomography*, *2*, 1–10.

BYDDER, G. M., BROWN, J., STEINER, R. E. & YOUNG, I. R., 1984. Use of intravenous gadolinium DTPA as a contrast agent in imaging of non-malignant disease of the brain. *Radiology*, *153*, 84.

BYDDER, G. M., CURATI, W. L., GADIAN, D. G., HALL, A. S., HARMAN, R. R., BATSEN, P. R., GILDERDALE, D. J. & YOUNG, I. R., 1985. Use of closely coupled receiver coils in magnetic resonance imaging; practical aspects. *Journal of Computer Assisted Tomography*, *9*, 987–996.

CLOW, H. & YOUNG, I. R., 1978. Britain's brains produce first NMR scan. *New Scientist*, *88*, 588.

DHSS, 1971. *Hospital Equipment Information No. 34. (DHSS, London.)*

——1975. *Health Equipment Information No. 57.* (DHSS, London.)

——1979. *Health Equipment Information No. 81.* (DHSS, London.)

1980a. *Health Equipment Information No. 84.* (DHSS, London.)

——1980b. *Performance Assessment of Gamma Cameras, Part 1.* Report No. STB/11/80. (DHSS, London.)

——1982. *Performance Assessment of Gamma Cameras, Part 2.* Report No. STB/13/82. (DHSS, London.)

——1985. *Performance Assessment of Gamma Cameras, Part 3.* Report No. STB6D/85/6. (DHSS, London.)

DONALD, I., MACVICAR, J. & BROWN, T. G., 1958. Investigation of abdominal masses by pulsed ultrasound. *Lancet*, *i*, 1188.

FISH, P. J., 1975. Multi-channel direction-resolving Doppler angiography. Proceedings of the 2nd European Congress on Ultrasonics in Medicine. Munich 12–16 May 1975. *Exerpta Medica International Congress Series No. 363.*

HANCOCK, C. W., 1981. The assessment of diagnostic X-ray equipment for the National Health Service. *Journal of X-ray Technology*, *2*, 3–14.

HAY, G. A., CLARKE, O. F., COLEMAN, N. J. & COWEN, A. R., 1985. A set of test objects for quality control in television fluoroscopy. *British Journal of Radiology*, *58*, 335–344.

HOLLAND, G. N., MOORE, W. S. & HAWKES, R. L., 1980. Nuclear magnetic resonance tomography of the brain. *Journal of Computer Assisted Tomography 4*, 1–3.

HPA, 1978. *The Theory, Specification and Testing of Anger-type Gamma Cameras.* Topic Group Report No. 27. (HPA, London.)

KREEL, L., 1977. Computerised axial tomography with tissue density, measurements (Report of March 1970). *Journal of Computer Assisted Tomography*, *1*, 1–5.

MARGULIS, A. R., 1985. Future directions of diagnostic imaging. *Proceedings of the XVI International Congress of Radiology*, Hawaii, 8–12, July 1985.

MAYNEORD, W. V., 1954. Radiological research. *British Journal of Radiology*, *28*, 309–317.

——1982. Closing remarks; the Mayneord Symposium. *British Journal of Radiology*, *55*, 699–700.

MCCARTY, K. & STEWART, W. R., 1982. A simple calibration and evaluation phantom for ultrasound scanners. *Ultrasound in Medicine and Biology*, *8*, 393–401.

MCCREADY, V. R., PARKER, R. P., GUNNERSEN, E. M., ELLIS, R., MOSS, E., GORE, W. G. & BELL, J., 1971. Clinical tests on a prototype semiconductor gamma camera. *British Journal of Radiology*, *44*, 58–62.

MONTGOMERY, J., 1972. *Techniques Used at AWRE in the Evaluation of Medical Ultrasonic Equipment.* Report No. GRO/44/83/105. (AWRE, Aldermaston.)

MYERS, M. J. & TOFTS, P. S., 1978. Longitudinal tomography using a simply modified rectilinear scanner. *Second Congress on Nuclear Medicine, London, 17–19 April, 1978.* European Society of Nuclear Medicine.

NRPB, 1981. Exposure to nuclear magnetic resonance clinical imaging. *Radiography*, *47*, 258–60.

ORDIDGE, R. J., MANSFIELD, P., DOYLE, M. & COUPLAND, R. E., 1982. Real-time movie images by NMR. *British Journal of Radiology*, *55*, 729–733.

PARKER, R. P., 1984. Medical imaging and its technological development in relation to cancer treatment. The first Mayneord lecture. *British Journal of Radiology*, *57*, 867–875.

WATSON, J. L., GORE, W. G., SPEARS, A. B. & WOLFE, P. A., 1971. A new scanning thermometer. *Journal of Physics, E, Scientific Instruments*, *4*, 1029–1035.

Book reviews

Pediatric Body CT. By Alan Daneman, pp. xv+374, 1987 (Springer-Verlag, London), £135.00.
ISBN 3-540-16217-8 (Berlin)
0-387-16217-8 (New York)

This book is based upon a 10-year experience of body computed tomography at the Hospital for Sick Children in Toronto during which some 5000 body scans were performed. Several previous adult books have contained chapters concerned with the application of the technique to children but this book relates solely to the problems of the young.

The introductory section considers, with reasonable detail, the preparation, sedation, scanning techniques and the use of contrast media. The relationship to other available techniques is considered and the information therein contained should be particularly useful to those whose paediatric practice is occasional.

Following this the book is divided into four sections: the chest, the abdomen, the neck and the musculoskeletal system. Computed tomography studies of the head, face and spinal cord are excluded on the grounds that there are other standard tests written by neuroradiologists on these subjects. Within each section an introductory chapter relates to the specific techniques and then chapters are orientated on an anatomical basis. For instance, in the chest section there are chapters on the mediastinum, lung parenchyma, chest wall and pleura.

Within each chapter the layout is essentially similar, with the anatomy, normal variants and congenital anomalies well described. Details of measurements of size and attenuation values are a pleasing and useful feature. Consideration of pathological processes is not confined to the presentation of images but includes clinical pathology, histopathology and the clinical features of the lesions.

The range of subject matter is extremely extensive and comprehensive, ranging from tarsal coalition and conjoint twins to careful assessment of pulmonary nodules with particularly comprehensive analysis of the pathology and evaluation of malignant disease. The illustrations are clear and well annotated; the majority of them have been performed on modern scanners but even those illustrations from earlier experience are adequate to indicate the points under discussion. After half the book consists of illustrations. The references are more than sufficient.

This book would prove particularly useful to those computed tomography units in which the majority of patients are adult and in which paediatric experience is necessarily limited. It would help not only in the acquisition of satisfactory images but also in their interpretation. Oncologists would also find it a useful source book. It is not very large at 370 pages although this does not mean that it is not adequately comprehensive, but at £135 it is very expensive.

D. G. SHAW

Manual of Fetal Echocardiography. By Lindsey D. Allan, pp. 175, 1986 (MTP Press, Lancaster), £22.50.
ISBN 0-85200-988-7

This book is the one all those interested in fetal echocardiography have been waiting for, encapsulating Dr Allan's unique experience in this field. The early chapters assume only a minimal knowledge of cardiac anatomy and very little knowledge of obstetric ultrasound. As a cardiologist the author has primarily aimed the book at those with an interest in cardiology, but goes to considerable trouble to make the book very readable for those with a more limited cardiac knowledge and a greater interest in obstetric ultrasound. The heart is analysed in a logical fashion with almost a third of the book devoted to normal anatomy. There are many useful hints which illustrate the author's very extensive practical experience in the subject. The only criticism is that the text and figures on most occasions are separated from one another. While this makes for easier reading of the text, it does mean the reader moving from text to figures which are sometimes several pages apart.

Overall the book is very well produced with high-quality illustrations and while its direct appeal is somewhat limited it would be very useful for every obstetric ultrasound department to have a copy. I am sure that all committed to obstetric ultrasound will find this a most interesting book.

D. W. PILLING

Pediatric Ultrasonography. By C. Keith Hayden Jr and Leonard E. Swischuk, pp. xiii+403, 1987 (Williams & Wilkins, Baltimore), £57.00.
ISBN 0-683-03900-8

This book, whose senior author (Dr Swischuk) is well known to most paediatric radiologists, sets out to cover the whole of ultrasound in the paediatric age group, spurred on by the rapid development of "real-time scanning" since the start of the decade. The book amply fulfils its aim. It has a very logical approach to the subject and gives helpful comparison between the value of the various imaging modalities in each particular clinical condition. There are many good practical tips and a very extensive bibliography. The authors explore even very minor interest areas such as the use of ultrasound in gastric ulcers, a very rare condition in children. The pictures are good but not outstanding.

This book is a very useful addition to the literature on paediatric ultrasound and would be valuable to both the specialist department and the general department doing some paediatric ultrasound. Those who know the authors' previous work will not be surprised that this book continues that excellent standard and can be thoroughly recommended.

D. W. PILLING

1987, *The British Journal of Radiology*, 60, 1059–1061 NOVEMBER 1987

A review of cervical-spine radiographs in casualty patients

By J. A. D. Annis, D. B. L. Finlay, M. J. Allen and M. R. Barnes

Departments of Radiology, Accident and Emergency, and Medical Physics, Leicester Royal Infirmary, Leicester

(*Received February 1987*)

ABSTRACT

This study reviews the radiographs and clinical case notes of 897 patients who attended the Accident and Emergency (A & E) Department of Leicester Royal Infirmary, over an 8-month period, for whom radiographs of the cervical spine were requested. The radiological interpretations by the casualty officers and junior radiologists in training were compared with those by a consultant radiologist and large discrepancies were observed. There was a predominance of fractures and subluxations at the levels of C1 and C2, and at C7 and T1. A study of the adequacy of the radiographs has shown that 90% of the lateral radiographs included C7 but only 57% included T1. Through-the-mouth views were adequate for interpretation in 67% of cases. The practice of the A & E and radiology departments at the Leicester Royal Infirmary is briefly described. The poor performance of the casualty officers and junior radiologists is discussed and suggestions made which might improve the accuracy of the radiological diagnosis of cervical-spine injuries in the A & E department.

This study was undertaken to assess the accuracy of diagnosis achieved by the examination of radiographs of the cervical spine taken in the Accident and Emergency (A & E) Department of Leicester Royal Infirmary over an 8-month period. Previous studies have examined the indications for radiography of the skull (Royal College of Radiologists, 1980) and of the extremities (Royal College of Radiologists Working Party, 1985). Other studies have assessed the accuracy of the reporting of casualty radiographs in general (Robson et al, 1985). In none of the studies was an assessment made of the accuracy achieved from radiography of the cervical spine. We have reviewed the radiographs and clinical information obtained from the casualty notes of those patients in whom cervical-spine radiographs were taken for trauma, acute pain and other acute symptoms located in the neck. Also included is a group in which the cervical spine was radiographed as part of the investigation into a variety of skeletal injuries, especially injuries of the skull.

METHOD

During an 8-month period 77 000 patients attended the A & E Department of the Leicester Royal Infirmary. Eight hundred and ninety-seven of these patients underwent radiography of the cervical spine, antero-posterior (AP), lateral and through-the-mouth views being used as standard. During the period of the study 14 casualty officers of Senior House Officer grade provided a 24-hour service. All decisions relating to the diagnosis and management of patients were made primarily by the casualty officers. The advice of more experienced doctors was always available.

There were six junior radiologists; four of these were registrars in their first year and the other two were in their third year of training. They examined the radiographs of the cervical spine on the day following the patients' attendance at the Accident and Emergency Department and had ready access to the opinion of senior radiologists if they chose to seek it.

The age and sex of the patients, the cause of injury to the cervical spine and all other relevant information, including associated injuries, was obtained from the casualty cards. The casualty officers' interpretations of the radiographs and the reports of the junior radiologists were collated. The radiographs were subsequently reviewed by a consultant radiologist with a special interest in orthopaedic radiology, without prior knowledge of the earlier reports or of the clinical history. The accuracy of the radiological diagnosis achieved by the casualty officers and the junior radiologists was assessed by comparison with the reports of the consultant radiologist.

RESULTS

The radiographs and casualty notes of 897 patients were examined. Fifty-eight per cent of the patients were male. The age range was 6 months to 98 years, the peak incidence of injury being in the second and third decades.

Clinical criteria for cervical spine radiographs

One hundred and twenty-eight (14%) patients underwent radiography of the cervical spine for conditions unrelated to spinal injury: 72 of these were performed as a precaution following head injury, in the absence of spinal symptoms. The remainder were performed for conditions such as torticollis, stiff neck and other painful conditions not related to trauma.

Seven hundred and three (78%) patients gave a history of injury to the cervical spine. Of these, 338 (48%) had been injured in a road traffic accident, the majority being "whiplash" injuries. The remaining 365

All correspondence to: Dr J. A. D. Annis, Department of Radiology, Leicester Royal Infirmary, Leicester LE1 5WW.

TABLE I

CLINICAL CRITERIA FOR CERVICAL SPINE RADIOGRAPHS

	No. of patients
History of injury to the cervical spine	703 (78%)
History unrelated to the cervical spine	128 (14%)
History not recorded by casualty officer	66 (8%)
Total	897 (100%)

(52%) had sustained injuries from a variety of causes, many of which were due to sporting activities. No clinical record was made in 66 (8%) patients (Table I).

One hundred and forty-nine (17%) patients also had significant injuries to other parts of the body, 93 of which were to the head. Of these 93, 72 had no associated spinal symptoms and radiography of the cervical spine was carried out as a precaution, which in one case revealed a fracture of C7. Of the remaining 21 with spinal symptoms, there was one fracture of T1 and one subluxation of C4 on C5.

Radiological diagnosis by casualty officers compared with consultant radiologist

Of the original 897 patients in the study, 594 sets of radiographs, which had been seen by the casualty officers, were available for review by the consultant radiologist. He found six subluxations of the cervical vertebrae, of which the casualty officers had found only two. The casualty officers had also diagnosed a further seven subluxations which the consultant radiologist was unable to confirm.

The consultant radiologist reported 17 fractures, of which only three had been diagnosed by the casualty officers. A further three fractures which were reported by the casualty officers were not confirmed by the consultant radiologist.

In total, therefore, of all radiologically demonstrable injuries, the casualty officers failed to recognise 18 out of 23 (78%) and erroneously diagnosed a further 10 (Table II).

Radiological diagnosis by radiologists in training compared with consultant radiologist

Only 471 sets of radiographs which had been seen by the junior radiologists were available for review by the consultant radiologist. He found five subluxations, of which two were recognised by the junior radiologists, who also misdiagnosed a further three.

TABLE II

COMPARISON OF THE RADIOLOGICAL DIAGNOSES BY THE CASUALTY OFFICERS AND THE CONSULTANT RADIOLOGIST

	Consultant radiologist	Casualty officers	
		True +	False +
Subluxations	6	2	7
Fractures	17	3	3
Total	23	5	10

TABLE III

COMPARISON OF THE RADIOLOGICAL DIAGNOSES BY THE JUNIOR RADIOLOGISTS AND THE CONSULTANT RADIOLOGIST

	Consultant radiologist	Junior radiologists	
		True +	False +
Subluxations	5	2	3
Fractures	12	3	0
Total	17	5	3

The consultant radiologist found 12 fractures, of which only three were identified by the junior radiologists.

Together the junior radiologists did not recognise 12 out of the 17 (70%) radiologically demonstrable injuries, and misdiagnosed a further three (Table III).

Sites of fractures and subluxations of the cervical vertebrae

In total, 27 fractures and subluxations were confirmed by the consultant radiologist. The distribution of these is shown in Table IV.

Adequacy of the radiographs that were reviewed

An AP view of the cervical spine was available in 773 sets of radiographs, a lateral view being available in 788. All of these showed the fifth cervical vertebra, 95% showed the sixth, 90% showed the seventh, but only 57% showed the first thoracic vertebra. The through-the-mouth view was adequate for interpretation in 601 sets of radiographs.

DISCUSSION

This study was designed to assess the accuracy of the radiological diagnosis of casualty officers and of junior radiologists in training, when interpreting cervical-spine radiographs of patients attending the A & E Department. It has revealed that the casualty officers did not make a correct diagnosis in 78% of the radiologically demonstrable injuries of the cervical spine, and

TABLE IV

THE LEVEL AND TYPE OF INJURY OF THE CERVICAL SPINE

Level of injury	Type of injury
C1	1 spinous process, 3 subluxations C1/C2
C2	3 odontoid peg, 1 extension teardrop, 1 spinous process
C4	1 extension teardrop, 2 subluxations C4/C5
C6	2 wedge fractures, 2 spinous process, 1 subluxation C6/C7
C7	2 burst fractures, 2 spinous process, 1 facet
T1	3 burst fractures, 2 wedge fractures

diagnosed a further three erroneously. The junior radiologists missed 70% of the injuries and also misdiagnosed three. It is possible that the casualty officers, having access to clinical information, allowed it to bias their interpretation of the radiographs. However, the junior radiologists, whose diagnosis was wholly radiological, also performed badly.

A study by Robson et al (1985) showed there to be a close correspondence between the reports of registrars in radiology and a consultant radiologist when reporting casualty radiographs. However, these radiographs were mainly of simple fractures or those that showed no abnormality. When interpreting changes seen on chest radiographs, which may be more ambiguous than simple fractures, there is shown to be a discrepancy of 20–30% between the reports of a registrar (trainee) in radiology and a consultant radiologist (Garland, 1959).

We have been unable to find any publication dedicated solely to assessing the accuracy of the interpretation of radiographs of the cervical spine. We believe this to be important because of the potential seriousness of cervical-spine injuries and also because of the difficulty of recognising fractures and subluxations, especially for inexperienced doctors. We believe that this study has revealed the extent of the problem.

We have used the opinion of one consultant radiologist as the standard against which the other interpretations were compared. We feel that this is justified as in everyday practice the opinion of one consultant radiologist is generally thought to be sufficient to establish a diagnosis. Unfortunately, not all of the radiographs were available for review by the consultant radiologist, as they were not always returned by clinical departments. However, he saw and reported on 594 sets which had been used previously by the casualty officers to establish a diagnosis. In addition, 471 reports made by the junior radiologists were available for comparison with the consultant's reports. We submit that the number of reports in each of these groups is sufficient for us to make valid comparisons; the more so because of the considerable differences in diagnostic accuracy that have been revealed.

The difficulty experienced by both casualty officers and junior radiologists may have been due not only to their lack of experience but also to deficiencies of radiography. These deficiencies were of two kinds, namely incorrect positioning and incorrect exposure factors. These problems are, to some extent, inevitable in a department where conditions for radiography are not always ideal, but the poorer-quality radiographs were presented to both the junior staff and the consultant. It seems probable that, with his greater experience, the consultant was better able to interpret radiographs of poor quality.

It is worth noting that five of the 21 fractures found occurred at the level of the first thoracic vertebra. However only 57% of the lateral views demonstrated this level. It would not be unreasonable to assume that a further four fractures of the first thoracic vertebra may have been present but were not demonstrated on the lateral radiograph. We therefore stress the importance of demonstrating T1 on all cervical spine radiographs taken for suspected injuries, thus supporting the views of Hampson et al (1984) in their case report.

This study has revealed serious errors by casualty officers and junior radiologists in the interpretation of radiographs of the cervical spine. The difficulty junior doctors have in reliably recognising fractures and subluxations of the cervical vertebrae has been demonstrated. We suggest that the performance of junior radiologists and casualty officers could be improved by recognition of this and appropriate adjustment of the training programme.

ACKNOWLEDGMENTS

The authors would like to thank Roberta Sutton for typing the manuscript and Mrs Nora Charlton for her help with the records.

REFERENCES

GARLAND, L. H., 1959. Studies on accuracy of diagnostic procedures. *American Journal of Roentgenology*, *82*, 25–38.

HAMPSON, S., COMMBS, R. & HEMINGWAY, A., 1984. Fractures of the upper thoracic spine—an addition to the "seat-belt" syndrome. *British Journal of Radiology*, *57*, 1033–1034.

ROBSON, N., VAN BENTHEM, P. P. & DIXON, A. K., 1985. Casualty X-ray reporting—a student survey. *Clinical Radiology*, *36*, 479–481.

ROYAL COLLEGE OF RADIOLOGISTS, 1980. A study of utilisation of skull radiography in 9 accident and emergency units in the UK. *Lancet*, *ii*, 1234–1236.

ROYAL COLLEGE OF RADIOLOGISTS WORKING PARTY, 1985. Radiography of injured arms and legs in 8 accident and emergency units in England and Wales. *British Medical Journal*, *291*, 1325–1328.

Book reviews

Angiocardiography. Current Status and Future Developments. Ed. by H. Just and P. H. Heintzen, pp. xi+403, 1986 (Springer-Verlag, Berlin), DM188.
ISBN 3-540-16562-2 (Berlin)
0-387-16562-2 (New York)

It is the hope of the editors "that the material assembled in this book gives an overview of what is currently available and what can be done with angiocardiography". The book assembles original work presented at a symposium held by the European Society of Cardiology at a time unstated. Eleven of the first twelve chapters deal with the characteristics of radiographic apparatus covering tube mounting and film changes, image intensifiers, video systems, digitisation of angiocardiograms, densitometry, photographic materials and contrast media. The level of these chapters varies from a historical review to a fairly complex analysis, but all would be of interest to radiologists, if only to refresh their memories. Then follow very basic chapters on the measurement of left ventricular volume and left ventricular muscle mass by angiocardiography and a chapter on the limitation of angiographic methods of assessing regional wall movement abnormalities. There are nine chapters devoted to ventricular systolic and diastolic function using a variety of approaches which virtually have in common only that X rays are involved in them.

A single rather basic chapter on pulmonary angiography is presented followed by sixteen chapters on coronary arteriography which range from a fairly straightforward presentation on the optimum choice of views for displaying the coronary arteries right through to computerised measurement of coronary artery stenoses and coronary artery flow. Congenital heart disease is referred to in only one chapter.

The book is well produced on high quality paper and well illustrated. In only a few chapters does the English betray any continental origin. To whom is the book directed and does it fulfil its stated aim? The earlier, basic equipment and principle chapters would be of interest to, and relevant to almost all radiologists, particularly those involved in vascular and cardiac radiology, as well as to cardiologists. The exotic computer applications will only be of interest to those who are either directly involved in image processing or who might want to refresh their knowledge as to how the whole field is going. Here, they might want to refer to a rather similar but more limited book by Reiber and Serruys (*State of the Art in Quantitative Coronary Arteriography*) which features the contributions of workers, some the same as, some different from those in the book above.

The problem with "work in progress" books, of which this is basically an example in its major part, is that by the time they come out they are often overtaken by events. All the papers in this book refer to purely research apparatus and are based on the digitisation of angiocardiograms recorded on film. It is now possible to record direct digital angiocardiograms simultaneously with the cine film and to apply the same computer processing principles, and extract the same left ventricular functional and coronary arteriographic data directly from the digitised images, in commercially available angiographic apparatus.

M. J. RAPHAEL

Pocket Atlas of MRI Body Anatomy. By Thomas H. Berquist, Richard L. Ehman and Gerald R. May, pp. x+97, 1987 (Raven Press, New York), $14.50.
ISBN 0-88167-282-3

Contained in this pocket atlas are 95 magnetic resonance (MR) images displayed in three orthogonal planes demonstrating normal body and limb anatomy. Most images have been obtained using a T_1 weighted spin-echo (SE) short time to repeat/short time to echo (600/25) sequence. The anatomy is labelled using numbers with legends at the top of the page. There is no text but a selected bibliography is included.

The MR images are of good quality, the extremities having been imaged using a surface coil. Although the plane of section is clearly indicated, an indication of right and left or anterior and posterior would have been helpful. Coronal and sagittal images of the limbs, especially depicting the neurovascular structures, would have added to the value of the atlas as would better images of cardiac chamber morphology and the coronary arteries. Despite the comment in the preface that the atlas is of interest to those learning cerebral anatomy there are no images of the head. No spinal anatomy is displayed apart from depicting surrounding musculature on body coil images.

Despite these criticisms, the atlas would be useful for radiologists, radiographers, interested clinicians and others as an introduction to magnetic resonance imaging.

R. J. JOHNSON

Clinical Imaging of the Pancreas. By Gerald May and Richard Gardiner, pp. xii+180, 1986 (Raven Press, New York), $48.50.
ISBN 0-88167-265-3

This book—part of a series published by Raven Press—is excellent. May and Gardiner, who are responsible for this volume, have managed in just over 200 pages to produce a book which is well written, clear in its aims and yet detailed.

From its introductory discussion on the embryology and development of the pancreas to the last chapter on traumatic lesions, one's interest is constantly maintained. The indications for the differing investigative modalities are clearly outlined and indicated—including the possible value of magnetic resonance imaging. A seven page chapter is given to a discussion of the congenital developmental anomalies which maybe found and to their clinical importance. Pancreatitis and pancreatic tumours are extensively covered—the differing stages of pancreatitis and rare pancreatic tumours are included in this. Features which are particularly valuable for radiologists are the clinical sections outlining presentation, complications, management and selection of imaging techniques.

The illustrations are clear and relevant and the "indicative arrows" are not unduly obtrusive. The references are up to date and the subject index comprehensive.

Radiologists, surgeons and physicians will all benefit from having the opportunity to read this book—$48.00 seems a very reasonable price to pay.

J. GLEESON

1987, *The British Journal of Radiology*, *60*, 1063–1065 NOVEMBER 1987

Real-time ultrasound measurement of bladder volume: a comparative study of three methods

By *G. G. Hartnell, M.R.C.P., F.R.C.R., †E. A. Kiely, F.R.C.S., Gordon Williams, F.R.C.S. and ‡R. N. Gibson, F.R.A.C.R.

Departments of Diagnostic Radiology & Surgery, Royal Postgraduate Medical School, Hammersmith Hospital, Du Cane Road, London W12 0HS

(*Received February 1987*)

ABSTRACT

The accuracy of different ultrasound methods for determining the volume of urine in the bladder was compared using three methods in current use. Each method was applied to the same ultrasound images from 16 patients with prostatic hypertrophy. The calculated volumes were compared with the true volumes derived by measurement of voided and catheter-drained urine. All methods showed similar degrees of accuracy in quantifying bladder volumes. The range of errors of the best method tested was ±35% of true volume and this suggests that ultrasound measurement of bladder volume is not sufficiently accurate for many clinical and research applications.

The use of ultrasound for the non-invasive study of bladder volumes was first described by Holmes (1967) nearly 20 years ago. Since then a variety of methods for measuring bladder volume has been reported. These have been applied to B-mode scanners (Harrison et al, 1976; McLean & Edell, 1978), hand-held scanners (Ravichandran & Fellows, 1983) and real-time scanners (Hakenberg et al, 1983).

Many of these reports claim that ultrasound is a reliable and repeatable method for measuring bladder volumes (Harrison et al, 1976; McLean & Edell, 1978). If this were true, ultrasound could be an important means of assessment of patients with a variety of functional disorders of the bladder, without the risks of catheterisation. Several different formulae have been compared in a small group of normal volunteers with very good results (SD 9%) (Griffiths et al, 1986). These are much better than those reported in patients with bladder outflow obstruction, suggesting that ultrasound assessment of bladder volume is less satisfactory in real patients than in normal volunteers. No studies have been reported which compare different methods in patients with bladder outflow obstruction.

We compared three widely used methods for measuring bladder volume by ultrasound (Rageth & Langer, 1982; Hakenberg et al, 1983; Poston et al, 1983). By applying the various methods simultaneously to the same patients we hoped to determine which is the most accurate and reliable method.

PATIENTS AND METHODS

Informed consent was obtained from 16 male patients (aged 54–90 years) with prostatic hypertrophy. Patients were initially examined when discomfort from a full bladder was experienced. Using a real-time ultrasound scanner (Diasonic CV400, 3.5 MHz transducer) bladder dimensions were measured, using electronic calipers, with the patient supine. Pairs of images were recorded in the parasagittal and transverse planes which gave the largest dimensions (Fig. 1). The measurements specified for each method were derived from the same ultrasound image. After voiding, further pairs of images were recorded to give an ultrasound measurement of residual bladder volume. Immediately after this the patient was catheterised and the true residual urine volume measured. The true residual volume was added to the voided urine volume to give the true initial bladder volume. The interval between the initial pre-voiding ultrasound examination and catheterisation did not exceed 15 min. No patients received diuretics or had polyuria.

For the method described by Hakenberg et al (1983) the bladder volume is calculated as $(0.625 \times H \times (D^1 + D^2/2) \times W)$ using the measurements illustrated in Fig. 1. Using the method of Rageth & Langer (1982) the outline of the bladder in the sagittal and transverse planes was traced using the electronic calipers to give areas in the two planes. Using these areas the bladder volumes were calculated from the table used in the original description of this method. Both of these methods were originally applied to real-time scanners. For the method of Poston et al (1983) the bladder volume is calculated as $(0.7 \times H \times W \times D^1)$. The original description of this method related to static B-mode scans. For this study we used the same scan planes using real-time scanning.

For each of the different methods the average of the two calculated volumes of each pair of scans was compared with the true initial and true residual bladder volumes measured from the voided and catheter-drained volumes. Although all patients had sympto-

---

*Author for reprints. Present address: Department of Radiology, Bristol Royal Infirmary, Bristol.

Present address: †Meath Hospital, Heytesbury Street, Dublin 8.

Present address: ‡Department of Radiology, Royal Melbourne Hospital, Parkville, Victoria 3050, Australia.

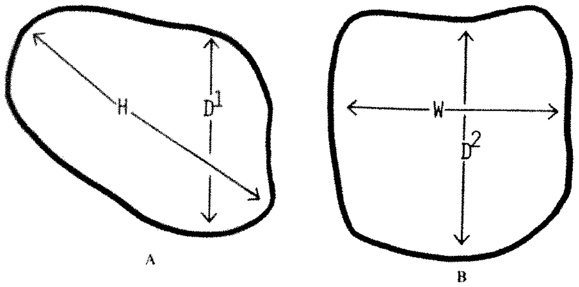


Fig. 1

(A) Sagittal measurements: H = greatest oblique diameter, D^1 = greatest vertical diameter. (B) Transverse measurements: W = greatest transverse diameter, D^2 = greatest vertical diameter.

matic benign prostatic hypertrophy, in no patient did the prostate project significantly into the bladder. Using linear measurements it was calculated that no prostatic impression into the bladder base occupied more than 30 ml of the bladder volume. All bladder outlines were fairly smooth and no bladder diverticula were identified.

Results

Sixteen patients were examined; one was examined twice, and three were unable to empty their bladders within a suitably short period. In all, 31 bladder volumes were calculated from linear dimensions. On seven occasions bladder volume could not be calculated from the image areas. In three cases the bladder areas were too great for calculation from the tables available (Hakenberg et al, 1983) and on four occasions the outline of the bladder was not sufficiently well defined around its base to allow accurate measurements. True bladder volumes ranged from 50 ml to 1260 ml.

The results obtained for the linear measurement methods on 31 occasions are shown in Table I. In addition, we applied a correction factor of 0.65 to the method described by Poston et al (1983) and found that this gave a better correlation with true bladder volumes.

Results for all the methods used were calculated separately for the 24 volumes where it was possible to apply the method of Hakenberg et al (1983) and are shown in Table II.

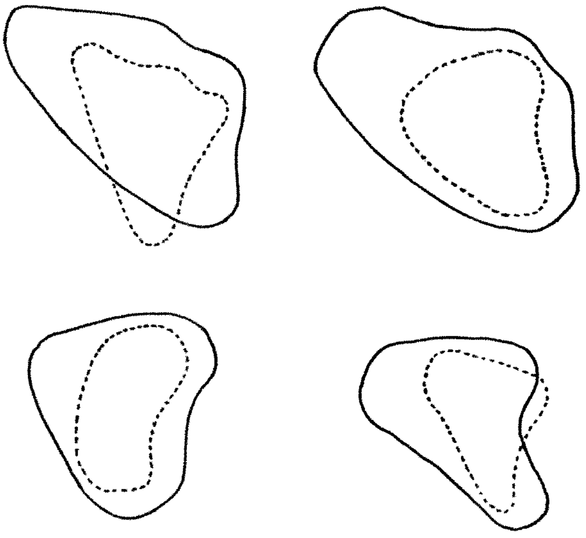


Fig. 2.

Outlines of sagittal scans of the bladder in four patients showing the variations in shape between patients pre-micturition (———) and post-micturition (— — —).

Errors varied at different true bladder volumes. The method of Poston et al (1983) tended to overestimate volumes at volumes under 250 ml. With volumes over 400 ml there was a wide range of errors although the mean error was less than at volumes under 400 ml. The method of Rageth and Langer (1982) overestimated volumes under 250 ml and underestimated volumes over 250 ml. The method of Hakenberg et al (1983) tended to underestimate volumes over 250 ml.

It was noted that there was considerable variability in the shapes of different bladders and at varying volumes (Fig. 2). Only two patients had true residual volumes of under 100 ml (65 ml and 50 ml). It is therefore not possible to make useful comment on the accuracy of these formulae at low bladder volumes.

Discussion

To our knowledge, this is the first occasion on which different published methods for measuring bladder volumes by ultrasound have been compared simultane-

TABLE I

Measurement errors for the methods of Poston et al (1983) (Method 1), Poston using a correction factor of 0.65 (Method 2) and Hakenberg et al (1983) (Method 3)

	Method 1	Method 2	Method 3
Range of volume errors (ml)	−121 to +384	−163 to +303	−180 to +326
Range of errors (%)	−29 to +52	−34 to +41	−35 to +44
Standard error (%)	20	17	17.5
Mean error (%)	+8	0	−2
Standard deviation from mean (%)	23	20	20

TABLE II

MEASUREMENT ERRORS IN THE 24 INSTANCES WHERE THE METHOD OF RAGETH & LANGER (1982) (METHOD 4) WAS APPLIED. COMPARISON OF ALL FOUR METHODS

	Method 1	Method 2	Method 3	Method 4
Range of volume errors (ml)	−121 to +191	−166 to +140	−180 to +120	−134 to +44
Range of errors (%)	−28 to +34	−33 to +28	−35 to +29	−35 to +22
Standard error (%)	20	16	17	15
Mean error (%)	+9	+1	−2	−8
Standard deviation from mean (%)	22	19	19	18

ously using the same ultrasound images from patients with bladder outflow obstruction. Our results confirm that ultrasound can be used to estimate the volume of urine within the bladder with a standard deviation for all methods of about 20%. The most accurate method is that described by Hakenberg et al (1983), but whether the minor improvement in accuracy justifies the longer examination time must be debatable. These methods are not applicable to all patients, either because the bladder outline is too indistinct or because the bladder is too large to demonstrate on a single scan.

In the original descriptions of the methods we tested, standard errors of 25% (Hakenberg et al, 1983), 21% (Poston et al, 1983) and 15% (Rageth & Langer, 1982) were reported. However, on closer examination of the graphical data available errors of over 300 ml (150%) (Hakenberg et al, 1983) and over 200 ml (100%) (Rageth & Langer, 1982) seem to have occurred. With errors of this magnitude it is difficult to support the claims for the usefulness of the techniques described. There are considerable variations in bladder shape which occur between different patients and within the same patient at different bladder volumes. It is therefore not surprising that these methods can be inaccurate. It seems likely that no formula applied to linear or circumferential measurements will improve on these results and that the only ultrasound methods which are likely to be significantly better are those derived from multiple tomographic sections (Beacock et al, 1985).

We have confirmed that all the methods tested can give rough estimates of bladder volumes, which may be all that is required in some clinical situations. However, the range of errors for all the methods used is significant and where an accuracy of better than 35% is required, real-time ultrasound is not a suitable alternative to measuring bladder volume by catheterisation. In spite of its attractions, we feel that the use of real-time ultrasound to measure bladder volumes is unsatisfactory for many clinical and research purposes.

REFERENCES

BEACOCK, C. J. M., ROBERTS, E. E., REES, R. W. M. & BUCK, A. C., 1985. Ultrasound assessment of residual urine. A quantitative method. *British Journal of Urology*, *57*, 410–413.

GRIFFITHS, C. J., MURRAY, A. & RAMSDEN, P. D., 1986. Accuracy and repeatability of bladder volume measurement using ultrasonic imaging. *Journal of Urology*, *136*, 808–812.

HAKENBERG, O. W., RYALL, R. L., LANGLOIS, S. L. & MARSHAL, V. R., 1983. The estimation of bladder volume by sonocystography. *Journal of Urology*, *130*, 249–251.

HARRISON, N. W., PARKS, C. & SHERWOOD, T., 1976. Ultrasound assessment of residual urine in children. *British Journal of Urology*, *47*, 805–814.

HOLMES, J. H., 1967. Ultrasonic studies of the bladder. *Journal of Urology*, *97*, 654–663.

MCLEAN, G. K. & EDELL, S. L., 1978. Determination of bladder volumes by gray scale ultrasound. *Radiology*, *128*, 181–182.

POSTON, G. J., JOSEPH, A. E. A. & RIDDLE, P. R., 1983. The accuracy of ultrasound in the measurement of changes in bladder volume. *British Journal of Urology*, *55*, 361–363.

RAGETH, J. C. & LANGER, K., 1982. Ultrasonic assessment of residual urine volume. *Urological Research*, *10*, 57–60.

RAVICHANDRAN, G. & FELLOWS, G. J., 1983. The accuracy of a hand-held real-time ultrasound scanner for estimating bladder volume. *British Journal of Urology*, *55*, 25–27.

Book reviews

Physics In Nuclear Medicine, 2nd edit. By J. A. Sorenson and M. E. Phelps, pp. xviii + 590, 1987 (Grune & Stratton, Orlando, Florida), $47.50.
ISBN 0–8089–1804–4

"Physics and instrumentation are of fundamental importance in nuclear medicine" say the authors, and this book aims to provide an introduction to the subject at a suitable level for a technician, doctor or scientist. The subject is covered from basic atomic and nuclear physics through descriptions of radioactivity, detector systems and interactions of radiation with matter, to the Anger camera and positron tomography. Radiation dosimetry, counting statistics, image quality and radiation safety are also considered, and there is a chapter entitled "Tracer kinetic modelling" which describes the various physiological models which are used to assist in analysing nuclear medicine data. There are some useful appendices giving data on medically important radionuclides, radiation doses and attenuation coefficients. Each chapter finishes with a few key references and a short bibliography from which the reader can obtain more detail on some of the subjects introduced.

The book is written in a simple, clear style and there are examples of calculations given to illustrate various practical points. Some knowledge of physics and mathematics is assumed, and the authors have not shrunk from inserting relevant equations and short mathematical derivations, but these are generally simple and the "non-mathematician" should not be discouraged by them. Illustrations are plentiful and pertinent, although in a few cases they are taken from other publications rather than produced specifically to illustrate the points in the text, and consequently are not always as easy to follow as they might be. Generally there is a tendency to use the old rather than SI radiation units, which is not so convenient for the UK reader; however, conversion factors are given.

Coverage of the subject is good and although I looked hard, I found few omissions. It is more perhaps a question of balance in the selection of material, which inevitably reflects a personal view. Thus, the chapter on tomographic systems devotes three times as much space to positron tomography as to gamma-camera tomography. There is an appendix devoted to the mathematics of convolution but nothing at all about deconvolution. The chapter on digital image processing is brief, with very little mention of parametric imaging and nothing on phase analysis. Whole-body counting gets one page. Neutron activation analysis is not mentioned—is it nuclear medicine?

But these are relatively minor criticisms. The book reminded me of *The Physics of Radiology* by H. E. Johns, smaller in size and format, but still nicely produced and comprehensive. It is a second edition and some detective work suggests that many of the chapters have undergone only minor revision, with references mostly dated before 1977, but these chapters deal mainly with the more basic aspects of the subject. Those chapters dealing with newer developments appear to have been rewritten or are wholly new. The only reason for being critical of a bibliography of books published 10–20 years ago is that they are likely to be out of print and less easily obtainable. However, perhaps it is an indication of the maturity of the subject that books of such age can still provide sound study material. I would recommend this as a good general textbook for a doctor, scientist or technician working in or studying nuclear medicine. For a prospective nuclear medicine physicist it would provide a fairly comprehensive introduction to the subject.

E. D. Williams

Diagnostic Nuclear Medicine: Patient Studies. By H. N. Wagner, J. W. Buchanan and D. Espinola-Vassallo, pp. xvi + 430, 1986 (Year Book Medical Publishers Inc, Chicago), $53.00.
ISBN 0–8151–9066–2

This book covers all aspects of nuclear medicine imaging, using selected case studies to illustrate the application of the different techniques. Each study is introduced as a clinical problem. A brief history is provided prior to the nuclear medicine investigation. Images from the investigation are presented, together with radiographs when appropriate. A description of the images follows together with an interpretation. The subsequent clinical course of the patient is then summarised. Several questions requiring yes or no answers are then posed to stimulate thought about the investigation of the clinical problem. This is followed by a reasonably extensive discussion and/or the nuclear medicine techniques used to diagnose or treat the problem. Answers to the questions are listed and each case study is concluded by a list of relevant references.

The studies are, in general, well chosen and stimulating. The illustrations are of excellent quality although arrows illustrating the salient features could be more widely used with advantage. The clinical data are succinct and relevant, although occasionally it is not clear why a particular investigation was performed. The "multiple choice" questions are thought-provoking, although occasionally rather artificial. The discussion sections are informative and valuable. Most commonly performed investigations are covered and a wide range of clinical problems included. One may quibble with some of the emphases; for example, gallium features extensively but there is little or no mention of ^{111}In leucocytes. Few centres as yet have access to positron emission tomography and cyclotron produced radionuclides. By and large however, a balanced picture of current nuclear medicine practice emerges.

Although not a systematic textbook of nuclear medicine, this volume can be strongly recommended to all those in training in nuclear medicine or diagnostic radiology and established practitioners will find much to refresh their memories, to stimulate their performance and in some cases to learn. The book is well produced with a good index and at £53.00 for 430 pages represents excellent value for money.

E. P. Wraight

1987, *The British Journal of Radiology*, 60, 1067–1070 NOVEMBER 1987

Percutaneous gastrostomy and gastro-jejunostomy

By Robin R. Gray, M.D., F.R.C.P. (C), Eugene L. St Louis, M.D., F.R.C.P. (C) and Harvey Grosman, M.D., F.R.C.P. (C)

Department of Radiology, The University of Toronto, The Wellesley Hospital, 160 Wellesley Street East, Toronto, Ontario, M4Y 1J3, Canada

(*Received October 1986 and in revised form March 1987*)

ABSTRACT

Percutaneous gastrostomy and gastro-jejunostomy are new techniques which may be used instead of surgical or endoscopic gastrostomy to feed patients with an intact small bowel. We have successfully performed 72 gastrostomies on 67 patients who had had unsuccessful procedures and required surgery. Two patients developed peritonitis when their catheter dislodged into the peritoneal space.

Percutaneous gastro-jejunostomy has recently been shown to be a feasible technique for enteric feeding of patients who are unable to ingest adequate nourishment (Wills & Oglesby, 1983, 1985; Ho, 1983; Ho et al 1984, 1985). This procedure is simpler and cheaper than surgical gastrostomy, and far easier to manage and less expensive than total intravenous alimentation.

Percutaneous gastro-jejunostomy may be preferable to surgical or endoscopic gastrostomy in patients with reflux and/or difficulty in defending their airways. Positioning the catheter tip in the jejunum provides extra protection against regurgitation. Percutaneous gastrostomy alone suffices when the oesophagus is obstructed.

Dislodgement of the feeding catheter before adhesions have developed between the stomach wall and the abdominal wall can result in infusion of the feeding solution into the peritoneal space and early dislodgement occurred in five of our cases. In retrospect, all patients exhibited a characteristic loop in the catheter which we now recognise as heralding potential dislodgement, and if observed should lead to catheter repositioning.

MATERIALS AND METHODS

Seventy-two percutaneous gastrostomies or gastro-jejunostomies were performed on 67 patients. The patients ranged in age from 21 years to 86 years. Forty-five were male and 22 female. Most gastro-jejunostomies were performed in 42 patients with neurological disorders who were either unable to swallow, or unable to protect their airways during swallowing. One patient was psychotic and would not eat and two had had oesophageal perforation during endoscopy. Pyloric obstruction secondary to peptic ulcer disease was the reason in one patient and another had facial burns and could not eat. Twenty-one patients had obstructing malignant disease of the pharynx or oesophagus. Gastric reflux and aspiration were clearly not problems in this latter group of patients so most had only gastrostomies.

Following placement of a nasogastric tube, the stomach was inflated with air. This makes the stomach a large target and also brings its anterior wall close to the abdominal wall. Dilating the stomach also displaces the transverse colon downward, allowing safe access to the stomach. In most cases the transverse colon is also full of air and one can clearly identify it fluoroscopically. Lateral fluoroscopy is used to be sure that neither the left lobe of the liver nor the transverse colon lie anterior to the stomach at the chosen puncture site, which is in the body of the stomach near the antrum with the needle angled slightly towards the antrum.

In our first 20 procedures we used a 21-gauge needle (Cook, DCHN-22-15) to make the initial puncture. A 0.018 in Lunderquist wire (Cook, TSCF-18-120-3-Lund) was passed through the needle after aspiration of air and injection of a small amount of contrast medium confirmed the intragastric location of the needle tip. A Schwartz introducer system (Cook, SCIS-1-Schwartz) consisting of coaxial 3 F and 6 F catheters were passed over the wire. Removal of the wire and 3 F catheter then allowed passage of a 0.038 in Lunderquist wire (Cook, TSCF-38-120-3-Lund) over which a steerable catheter (Cook, BDS-6.5-38-65-M-2S-C2) could be introduced to negotiate the pylorus. Once the catheter and wire had been passed to the ligament of Treitz, the track was dilated to 10 F and a Gray jejunostomy catheter (Cook Canada, GJG-10-0-50-Gray) inserted. This catheter has multiple side-holes clustered near the tip and is soft enough to be left in place for prolonged periods.

In the last 52 procedures, we have abandoned the cumbersome "skinny" needle approach and now make the initial puncture with an 18-gauge "splenic" needle (Cook, DTN-18-15.0) and go directly to the 0.038 in wire. We have found that a rotatory movement of dilators during insertion prevents the gastric wall being pushed away from the dilator tip. A straight push of the dilator may displace the stomach back along the wire

---

Reprint requests to: Robin R. Gray, M.D., The Wellesley Hospital, Department of Radiology, 160 Wellesley Street East, Toronto, Ontario, M4Y 1J3, Canada.

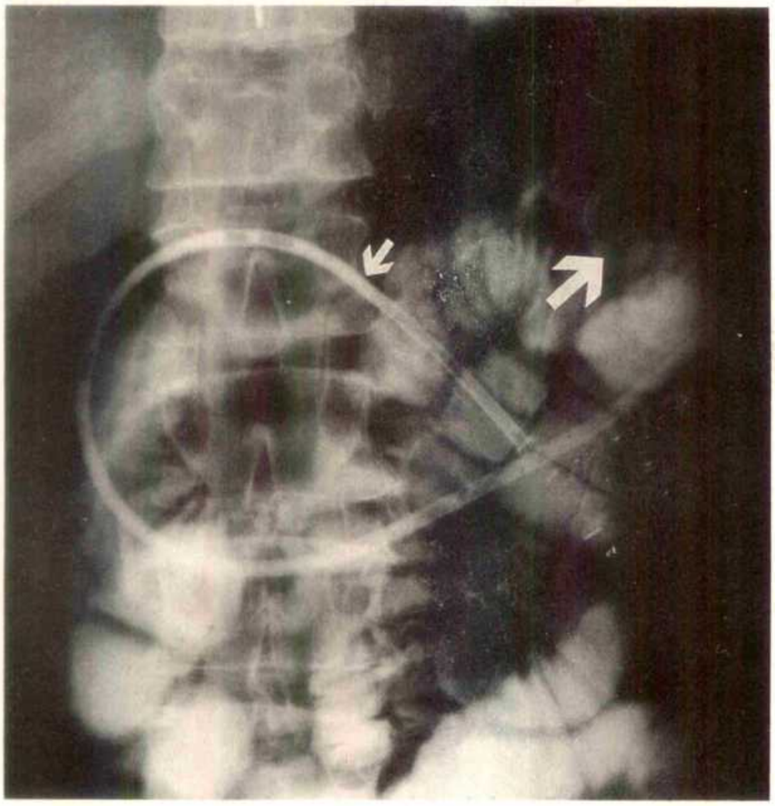


FIG. 1.

A normally positioned catheter. The small arrow indicates the site of catheter entry into the anterior abdominal wall. The large arrow shows the catheter tip.

and result in loss of wire position. The normal catheter position is shown in Fig 1.

When only gastrostomy was performed, the track was serially dilated to 10 F over the 0.038 in wire and a 10 F Cope loop nephrostomy catheter (Cook, PU-10-38-25-P-45-NCL) placed in the body or the fundus of the stomach. The gastrostomies took only 15 min if the patients had a nasogastric tube. Placing the nasogastric tube past an oesophageal obstruction using steerable catheters and guidewires added another 30 min in three cases.

Procedure time for gastro-jejunostomy ranged from 15 min to 90 min, with a mean of 30 min.

RESULTS

Seventy-two procedures were performed successfully in 67 patients, five having two procedures each. There were 51 gastro-jejunostomies and 21 gastrostomies.

There were two unsuccessful attempts to effect a gastro-jejunostomy which are not included in the 72 successful procedures described previously. The second patient in whom we attempted the procedure had a successful gastric puncture and dilatation of the stomach to 12 F but the feeding catheter could not be passed. This was subsequently found to be the result of binding on the trocar. During manipulation, the guidewire became dislodged so the procedure was discontinued. At surgical gastrostomy the next day no hole was seen in the gastric wall, nor was there any spillage of gastric content. This case gave us great confidence in the safety of gastric-wall puncture, knowing that even a 12 F hole could close off completely. On two subsequent occasions when we lost guide-wire access to the stomach, we simply repunctured and completed the procedure uneventfully.

The other failure was in a patient who, although having had a successful puncture and gastrostomy, unfortunately had a huge hiatius hernia with volvulus of the stomach and it was not possible to negotiate the pylorus. The gastrostomy could not be used for feeding because there was massive gastro-oesophageal reflux. In retrospect, this procedure should not have been attempted but we did not appreciate the presence of the volvulus prior to puncturing the stomach. This man died following surgical jejunostomy.

Five early dislodgements occurred which showed a characteristic looping and kinking of the catheter (Fig. 2) and three of these patients underwent a repeat procedure. The other two developed peritonitis and required laparotomy with surgical gastrostomy and peritoneal lavage. There were 12 dislodgements more than a week after the procedure, of which five occurred serially in one patient. None of these patients had any sequelae, and in 11 instances the gastro-jejunostomies

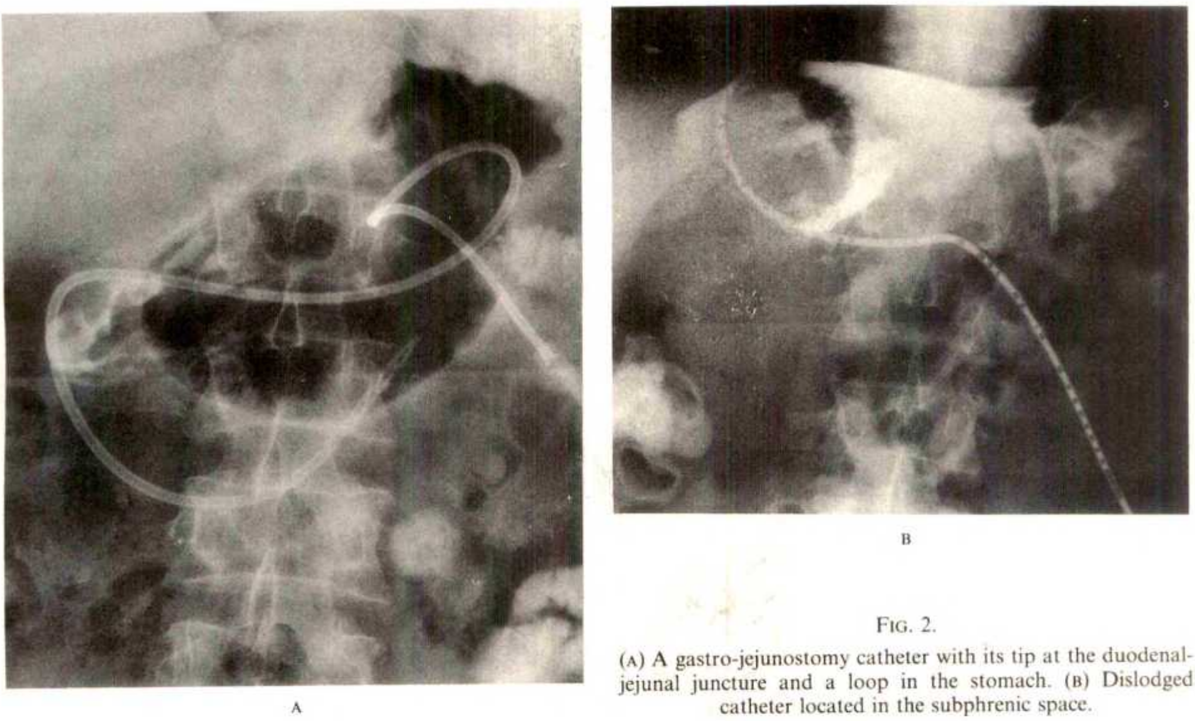


FIG. 2.

(A) A gastro-jejunostomy catheter with its tip at the duodenal-jejunal juncture and a loop in the stomach. (B) Dislodged catheter located in the subphrenic space.

were recannulated without difficulty through the original track. One patient required a new procedure because the track had closed prior to his arrival in the radiology department.

Twelve of the 10 F catheters became occluded, the mean time from insertion to occlusion being three months, with a range of two weeks to seven months. Replacement of the occluded catheters was usually easily accomplished over a guide-wire. Sometimes the obstructing material was so dense that a guide-wire could not be passed. In these circumstances, the catheter was removed through a sheath or simply withdrawn, in which case the track was recannulated with a "floppy" J guide-wire. However, on four occasions when our 10 F catheters were not available 7 F or 8 F pigtail angiographic catheters were used as a temporary measure. In all cases the smaller angiographic catheters became blocked within 10 days and had to be replaced.

DISCUSSION

Surgical gastrostomy has been in use for over 100 years and until the 1950s was associated with a high rate of complications. Significant complication rates are still encountered, bleeding, leakage, perforation and ulceration being among the most serious, and aspiration (with or without pneumonia) the most common (Wilkinson & Prickleman, 1982; Burtch & Shatney, 1985). Aspiration rates of up to 36% have been reported (Burtch & Shatney, 1985) and the value of the procedure has been questioned by Burtch & Shatney (1985).

Ponsky has popularised a combined endoscopic–percutaneous method of placing a feeding gastro-jejunostomy (Ponsky & Aszodi, 1984) but this seems unnecessarily cumbersome.

Percutaneous gastrostomy is useful as an alternative to surgical gastrostomy or total parenteral nutrition in patients with an intact small bowel (Ho et al, 1984, 1985; Wills & Oglesby 1985), particularly those with oesophageal obstruction or aspiration. It is cheaper than total parenteral nutrition and can be used in place of the traditional surgical gastrostomy in patients requiring enteric feeding who have not had a previous gastric resection and whose stomach is accessible below the costal margin.

The major potential complication is dislodgement of the tube. The gastrostomies are held in place by the Cope loop device. The gastro-jejunostomies are held in place by catheter length and peristalsis. Several varieties of retention device have been developed to help prevent dislodgement of jejunal tubes (Brown et al, 1986; Van Sonnenberg et al, 1986). We divide dislodgements into two categories. The first is late dislodgement after the patient has been successfully fed through the tube for a period of a week or more. This minor complication results most commonly from demented patients pulling out the tube. If recognised early it can be treated simply by passing a guide-wire through the track and reintroducing the catheter. After approximately 1 week, adhesions develop between the stomach and the abdominal wall and there is no difficulty in replacing the catheter, nor is there any problem with spillage into the peritoneal space. We have had 12 instances in which the gastrostomy catheters were pulled out after at least 1 week. In those patients who were brought to the X-ray department within a few hours of dislodgement, injection into the skin wound showed a continuous track from skin to stomach lumen, with no peritoneal leak. Adhesions and fibrous track formation across the peritoneal space are similar to those occurring in biliary and abscess drainage procedures.

Early dislodgement occurs within the first week. If the catheter is pulled out completely, the procedure must be repeated. However, if it is dislodged internally, this is a much more serious complication. Dislodgement in the immediate post-procedural period means that adhesions have not developed between the stomach and the abdominal wall. The catheter, while appearing normal at the skin may in fact be free in the peritoneal space with consequent infusion of the feeding solution into the peritoneal space, which may cause peritonitis.

The five cases in which we have seen early dislodgement all showed a sharp kink at the entry site and a loop in the catheter projecting into the fundus. This appearance was not seen in any of the gastro-jejunostomies in which the catheter remained in place. All but one of these five patients were being artificially ventilated and this may contribute to excessive movement between stomach and abdominal wall. No patient who had a normal catheter configuration had an internal (*i.e.* into the peritoneal space) dislodgement. This configuration, therefore, should serve as a warning of this potential complication and immediate efforts should be made to reposition the catheter to eliminate any bending in the pre-pyloric portion.

None of our gastrostomy catheters has dislodged (follow-up up to 6 months) since these all have a Cope loop retention device.

By the time the catheters become blocked, the track is usually well established and larger tubes can be inserted without difficulty.

In conclusion, percutaneous gastrostomy and gastro-jejunostomy are safe, technically easy and relatively cost-effective procedures for those patients unable to ingest adequate nourishment. Gastrostomy is adequate for those with oesophageal obstruction. Positioning the tube in the jejunum is preferable when reflux or aspiration is likely to occur.

REFERENCES

Brown, A. S., Meuller, P. R. & Ferucci, J. T., 1986. Controlled percutaneous gastrostomy: nylon T-fastener for fixation of the anterior gastric wall. *Radiology, 158*, 543–545.

Burtch, G. D. & Shatney, C. H., 1985. Feeding gastrostomy: assistant or assassin. *American Surgeon, 51*, 2024–2027.

Ho, C. S., 1983. Percutaneous gastrostomy for jejunal feeding. *Radiology, 149*, 595–596.

Ho, C. S., Gray, R. R., Goldfinger, M. & Rosen, I. E., 1984. Percutaneous gastrostomy for enteral feeding. *Radiology, 153(P)*, 255.

Ho, C. S., Gray, R. R., Goldfinger, M., Rosen, I.E. & McPherson, R., 1985. Percutaneous gastrostomy for enteral feeding. *Radiology, 156*, 349–351.

Ponsky, J. L. & Aszodi, A., 1984. Percutaneous endoscopic jejunostomy. *American Journal of Gastroenterology, 79*, 113–116.

van Sonnenberg, E., Wittich, G. R., Cabrena, O. A., Quinn, S. F., Casola, G., Lee, A. A., Princenthal, R. A. & Lyons, J. W., 1986. Percutaneous gastrostomy and gastroenterostomy. 2. Clinical experience. *American Journal of Roentgenology, 146*, 581–586.

Wilkinson, W. A. & Prickleman, J., 1982. Feeding gastrostomy, a reappraisal. *American Surgeon, 48*, 273–275.

Wills, J. S & Oglesby, J. T., 1983. Percutaneous gastrostomy. *Radiology, 149*, 449–453.

Wills, J. S. & Oglesby, J. T., 1985. Percutaneous gastrostomy: further experience. *Radiology, 154*, 71–74.

1987, *The British Journal of Radiology*, 60, 1071–1081 NOVEMBER 1987

Evaluating and comparing imaging techniques: a review and classification of study designs

By Laurence S. Freedman, M.A., Dip. Stats.

Cancer Trials Office, MRC Clinical Oncology and Radiotherapeutics Unit, MRC Centre, Hills Road, Cambridge CB2 2QH

(*Received January 1987 and in revised form February 1987*)

ABSTRACT

The designs of studies to evaluate and compare imaging techniques are reviewed. Thirteen principles for the design of studies of diagnostic accuracy are given. Because of the "independence principle" these studies are not able directly to evaluate the contribution of a technique to clinical management. For the latter, the "clinical value" study design is recommended. A classification of study designs is proposed in parallel with the standard classification of clinical trials. Studies of diagnostic accuracy are analogous to Phase II, whereas studies evaluating the contribution to clinical management correspond to the Phase III category. Currently the majority of published studies employ the Phase II design. More emphasis on Phase III studies is required.

Over the past 20 years several new methods of generating images of internal organs and anatomy of the body have been developed and used to enhance the accuracy of diagnosis and treatment. These include ultrasonic scanning, radionuclide scanning, computed tomography (CT) and magnetic resonance imaging (MRI). The new techniques have made a considerable impact on radiological practice in hospital departments, not least on the investigational process for patients suspected or known to have malignant disease.

As a consequence of the increased range of available imaging techniques and of their relative novelty, there has developed a need to evaluate and compare their usefulness. This paper aims to examine the statistical designs and analyses which have been used. The paper begins with a brief review of the different types of study. Examples of each type are then chosen to illustrate statistical issues related to their design and analysis. In the final sections it is argued that a form of classification for these different types of study might be helpful in clarifying relationships between them and bringing a perspective to the field. A classification, based upon a limited analogy with clinical trials, is suggested.

STUDY DESIGNS EMPLOYED TO EVALUATE IMAGING TECHNIQUES

Studies that have been conducted to evaluate or compare imaging techniques may fall under one of the following five broad headings, four of which are subsequently discussed in detail.

Pilot studies

These are concerned with the feasibility of a new technique and address questions such as the acceptability of the method to patients and hospital staff and the quality of the images (*e.g.* Hawkes et al, 1980). These studies do not comprise any formal evaluation. Necessary as they are, their statistical content is negligible and they will not be dealt with in more detail.

Diagnostic accuracy

To evaluate diagnostic accuracy, patients are assessed by the imaging technique under study and the radiologist's diagnosis is compared with a final, or "gold-standard", diagnosis. This type of assessment is currently the most common to appear in the literature. It should be noted that the term "diagnostic accuracy" uses the concept of diagnosis in its broadest sense. For example, a study of CT in the staging of a cancer by comparing CT evaluation of lymph nodes with a subsequent biopsy result would be termed a diagnostic accuracy study.

Clinical value

These studies aim to evaluate the contribution of an imaging technique to the clinical management of the patient. The typical design consists of an assessment made by the clinician before receiving the radiologist's report and again after receiving it. The impact of the technique on both the diagnostic and therapeutic process may be studied in this way.

Randomised comparisons

These have only rarely been conducted to evaluate imaging techniques. Typically, the patient is allocated one of two imaging techniques or policies by randomisation and is then followed to assess various outcome measures. The two groups of patients are then compared with respect to these outcome measures.

Before-and-after studies

These may be chosen when an imaging policy is replaced by a new one in a particular hospital. The typical study is a comparison of diagnostic practice before and after the introduction of major new technology, such as CT.

STUDIES OF DIAGNOSTIC ACCURACY

Since studies of diagnostic accuracy are the most commonly performed, they will be treated in the most detail.

A typical example of this type of study is reported by Husband et al (1977), in which ultrasound and CT were compared prospectively for the diagnosis of a series of 63 patients with suspected pancreatic disease. Various aspects of study design and analysis will be considered in the context of Husband et al's report.

Final diagnosis

As mentioned above, diagnostic accuracy is measured in relation to a final "gold-standard" diagnosis. The rules for establishing the final diagnosis are most important. Husband et al report: "The final diagnosis was obtained either by laparotomy, post-mortem or by strong biochemical or clinical evidence of disease." They hint at a vital principle here, that the final diagnosis must be established independently from the imaging technique under evaluation. The reason is quite obvious. Allowing the technique to contribute to the final "gold-standard" diagnosis is no different from allowing a candidate to mark some of his own examination papers. It is surprising how often this simple principle is forgotten and many reports do not say explicitly whether the final diagnosis was independent of the imaging technique. In Husband et al's report, there is a remark, "The initial reports issued to the referring clinician . . .", which indicates that the clinicians knew of the results of the imaging tests before establishing the final diagnosis. The reader is left to speculate on the effect of allowing the results of these tests to determine, possibly, what other investigations were required to establish the final diagnosis.

In summary, the independence principle strictly requires that the results of the imaging techniques are not given to the clinician-in-charge before diagnosis has been established so that they do not influence the diagnostic process.

While this principle preserves the integrity of studies of diagnostic accuracy it also limits its usefulness. The artificiality of blinding the clinician-in-charge to the imaging result prevents the investigator from assessing the imaging technique in a natural clinical setting. This is discussed below.

In many clinical situations a definite final diagnosis may be difficult to obtain. Sharp et al (1985) cite suspected liver metastases as an example. For imaging studies it is important to avoid reliance on another imaging technique, since this itself may not be completely reliable. The ideal, particularly in oncology, is to use autopsy or histological evidence. Otherwise, two strategies have been used in the face of this difficulty. The less radical solution (Reid et al, 1983) is to grade the reliability of the final diagnosis by introducing a diagnostic rating. Such a rating, on a nine-point scale, is shown in Table I. A simple way of using the scale is to exclude from analysis all patients with a particularly doubtful rating; *e.g.* excluding between 2 and 5 on the scale would be equivalent to demanding biopsy, laparotomy or post-mortem proof. More sophisticated uses of the ratings are possible but have not been developed.

The other strategy to meet difficulties with the final diagnosis has been to dispense altogether with an "objective" measure of diagnostic accuracy and use another measure in its place. For example, Hauser and Gottschalk (1978) compared a tomographic camera with a gamma camera technique by eliciting the preferences of nuclear medicine physicians for one or another set of images in a series of patients. The results from these studies, although of some use, do not allow strong conclusions to be made about the accuracy of the techniques and the design is limited to *comparison* of techniques.

Selection of patients

How should one select the patients to be entered into a study of diagnostic accuracy? Husband et al (1977) included in their study "a total of 63 consecutive patients with suspected pancreatic disease" but excluded from analysis 13 with follow-up information which was inadequate to establish a firm diagnosis. Of the 50 patients in the analysis, 16% had acute pancreatitis, 32% chronic pancreatitis and 24% malignant disease. These proportions, no doubt, reflect the specialist centre at which the study was conducted.

Foster et al (1984), in a district hospital, found that out of 107 patients in the study only 17 (16%) had a final diagnosis of chronic pancreatitis (11 patients) or pancreatic neoplasm (six patients). Naturally the smaller numbers of diseased patients reduce the precision with which diagnostic accuracy may be measured. However, Foster et al claim that "investigators have assessed the tests in populations comprising 25–50% of patients with disease" which "necessarily implies an element of selection . . . and artificially enhances sensitivity and specificity."

Ranshoff and Feinstein (1978) emphasise a similar point, that within the "diseased" group of patients (*e.g.*

TABLE I

Rating of final diagnosis of liver disease

Rating	Results from biopsy	Other evidence (laparotomy or post-mortem)
0	Negative	Negative
1	Negative	Positive or conflicting
2	None available/equivocal	Negative
3	None available/equivocal	Conflicting but probably negative
4	None available/equivocal	Conflicting
5	None available/equivocal	Conflicting but probably positive
6	None available/equivocal	Positive
7	Positive	Negative or conflicting
8	Positive	Positive

Adapted from Reid et al (1983).

colonic cancer) the accuracy of the test may vary with pathological type of disease and clinical stage. Similarly within the "non-diseased" group the accuracy of the test may differ according to the patient's condition; in particular the test may be more likely to yield false positives for patients with conditions similar to the disease (*e.g.* colitis or carcinoma of the breast).

The important principle which underlies these comments is that, ideally, the imaging technique should be tested in a group of patients who are representative of the target population, that is, the patients for whom the technique is intended in the future. Failing this an effort should be made to include a wide enough spectrum of patients to cover the composition of the target population. Even though the study group may not contain the various subgroups of the population in the same proportion, it is possible to make correction once the distribution of subgroups in the target population is ascertained.

Performance of the imaging technique

Husband et al note that "the quality of the final ultrasound image is highly dependent upon the skill of the operator." Sharp et al (1985) remark that results obtained by a highly-skilled operator in a research environment are likely to overestimate the diagnostic accuracy of a new technique. The acid test for the technique will be in routine hospital service and the study should therefore evaluate the technique in such an environment.

Husband et al (1977) report that the radiologist conducting the examinations "had access to a summary of the clinical problems, together with all relevant radiological and laboratory data." It is the normal clinical practice to supply the radiologist with relevant information. To do so in a study of diagnostic accuracy is to evaluate the accuracy of the imaging technique combined with the knowledge of other commonly available information. Some would argue that it is more informative to evaluate the contribution of the imaging technique independently of the other information, and therefore advocate a "blind" assessment. This is a point of view that may be worthy of consideration. A good compromise might be to use a two-stage reporting process, first without the benefit of any clinical data and second taking these into account. This would allow evaluation of both "blind" and "open" reporting of the results of the technique. It may be found, for example, that the level of accuracy of the blind assessment is more reproducible among different pathologists than the accuracy of the open assessment, because of differences in the way the extra data are used in reporting. Some empirical evidence is needed in this debate.

Comparative studies

Although a study of diagnostic accuracy is both feasible and informative when applied to a single imaging technique, studies comparing two or more techniques will generally yield more useful information. The study of Husband et al is an example of a comparative study. These investigators were careful to ensure that each patient received both imaging investigations on the same day.

If there is a considerable proportion of patients whose diagnostic tests have been missed, the investigators should consider the possible effect on the results. Foster et al (1984) indicate that 20% of their patients had no CT but do not mention why this occurred or whether this could have biased the final results in any way.

Just as the results of the imaging technique should not be allowed to influence the final diagnosis, so one technique under study should not be allowed to influence the performance of the competing technique. Thus Abrams et al (1982), in a comparison of CT and ultrasound, were wrong to permit that "in some patients who had CT first, with definitely negative or positive results, ultrasound was omitted."

Measures of diagnostic accuracy

The results of a study of diagnostic accuracy are usually reported in the form of summary measures such as accuracy, sensitivity and specificity. This section discusses the definitions and uses of these measures.

The definitions of these measures involve two assumptions: (1) that one particular disease is of interest and (2) that the result of the imaging technique is reported as either negative or positive for the disease in question. All of the summary measures under discussion reflect the success of the imaging technique to detect the disease chosen for study. It should be recognised that these assumptions are often at variance with routine clinical practice. Radiologists in their report will mention several possible diseases, giving each an informal rating of its likelihood. Thus, contrary to the first assumption, the clinical interest may be in the ability of an imaging technique to differentiate between a set of, say, six possible diseases; and contrary to the second assumption, the radiologist may report that Disease A is most probable, Disease B is a second possibility and that Disease C, although rare, should not be discounted, whereas D, E and F can be ruled out.

The objection to the first assumption may be overcome by calculating the summary measure for each disease in turn. Thus, in Foster et al (1984) patients may have had a final diagnosis of chronic pancreatitis, acute pancreatitis, carcinoma or no definitive diagnosis (*i.e.* assumed normal). To examine the success of CT in detecting carcinoma, patients would be classified as carcinoma or "other"; the "other" category would include all patients without carcinoma. The success of CT in detecting chronic pancreatitis could be examined by dividing patients into the two groups chronic pancreatitis and "other", where "other" now includes all patients without chronic pancreatitis; and so on for other diseases.

The objection to the second assumption may be overcome by the use of analysis of receiver operating characteristic (ROC) curves, to be described in the next section. The ROC curves cater for the situation where the radiologists report the results of the imaging technique with varying degrees of certainty, but the method does not enjoy the ease of interpretation afforded by the summary measures to be described.

We now discuss the summary measures, assuming that the result of the technique is positive or negative for the disease of interest and the final diagnosis is either diseased (having that disease) or disease-free (not having it). Each summary measure is defined in the text and the calculation is illustrated in Table II, taken from Frankl and Ackerman (1977) who report a study of mammography in the diagnosis of breast cancer.

Much confusion has arisen over the use and terminology of measures of diagnostic accuracy. Six terms are in general use: reliability, accuracy, sensitivity, specificity, positive predictive value and negative predictive value.

Reliability. The reliability of a technique concerns the reproducibility of the result. We may refer to the reproducibility from test to test or from observer to observer or from time to time by the same observer. Reliability may be measured without reference to an external diagnosis and therefore does not require a study of diagnostic accuracy (as understood in this article) for its determination. Reliability assessment involving repeat assessments of the same patient within a short interval and separate blind evaluations of each image by different radiologists could be built into a study of diagnostic accuracy or carried out beforehand. Serious unreliability will lead to an imaging technique which is not consistently accurate.

Accuracy. Accuracy is often used as a non-technical description of the ability of a technique to yield the correct diagnosis. Confusingly, it has also come to be used in a technical sense meaning "the proportion of test results (positive or negative) which agree with the final diagnosis (diseased or disease-free)". The accuracy of mammography in diagnosing breast cancer is estimated by Frankl and Ackerman (1977) to be 66% [(547 + 786)/2005] (Table II). This measure, although intuitively appealing, makes no distinction between the information contained in a positive from that contained in a negative test result. It therefore tends to mask important properties of the imaging technique and has fallen from favour, and the most commonly used measures are sensitivity and specificity.

TABLE II

DIAGNOSIS OF BREAST CANCER BY MAMMOGRAPHY

Biopsy	Mammography		Total no. patients
	Positive	Negative	
Malignant	547	12	559
Non-malignant	660	786	1446
Total no. of patients	1207	798	2005

Accuracy = (547 + 786)/2005 = 66%
Sensitivity = 547/559 = 98%
Specificity = 786/1446 = 54%
Positive predictive value = 547/1207 = 45%
Negative predictive value = 786/798 = 98%
Prevalence = 559/1446 = 39%

Data from Frankl and Ackerman (1977).

Sensitivity. Sensitivity is defined as "the proportion of diseased patients who are reported positive". From Table II, the sensitivity of mammography is estimated as 98% (547/559).

Specificity. There is some confusion over the term specificity. Its definition in epidemiology and in other areas of diagnostic medicine is "the proportion of patients free of the disease who are reported negative". (Many radiologists use the term specificity to mean the proportion of patients reported positive for the disease who are finally diagnosed with that disease. This is incorrect in so far as it does not accord with the rest of diagnostic medicine. The correct term for this measure is positive predictive value—see below.) From the data in Table II, the specificity of mammography is estimated as 786/1446 = 54%. It can be seen that, in this study, there was a large number of false positives (*i.e.* positive results in disease-free patients) leading to low specificity.

Sensitivity and specificity have the statistical property that their values are independent of the prevalence of (*i.e.* how commonly patients present with) the disease. This property has peculiar advantages and disadvantages. The principal advantage is that the results of studies carried out in patient populations with different prevalences of the disease under study can, theoretically, be compared using sensitivity and specificity. This perceived advantage has recently been weakened by the realisation that differences in the spectrum of study patients can indeed affect the estimates of sensitivity and specificity (see Selection of Patients). The principal disadvantage in the use of sensitivity and specificity is that they do not, by themselves, tell the investigator how useful the imaging technique will be in practice. Two measures of accuracy which *do* provide this information are the positive and negative predictive values.

Predictive values. The positive predictive value is defined as "the proportion of patients reported positive who have the disease," the negative predictive value as "the proportion of patients reported negative who do not have the disease". Returning to the data in Table II, the positive predictive value is 547/1207 = 45%, while the negative predictive value is 786/798 = 98%. These values give us direct information about how much reliance can be placed on the imaging result. If there is a positive result there is roughly a one in two chance (45%) that the patient has breast cancer. This is strong

TABLE III

FORMULAE LINKING SENSITIVITY, SPECIFICITY, PREVALENCE AND PREDICTIVE VALUE

$$\text{Positive predictive value} = \frac{\text{sensitivity}}{\text{sensitivity} + ((1 - \text{specificity}) \times (1 - \text{prevalence}) \div \text{prevalence}))}$$

$$\text{Negative predictive value} = \frac{\text{specificity}}{\text{specificity} + ((1 - \text{sensitivity}) \times \text{prevalence} \div (1 - \text{prevalence}))}$$

If we apply the sensitivity and specificity of Table III to a prevalence of 1% (0.01) we obtain:

$$\text{Positive predictive value} = \frac{0.98}{0.98 + ((1 - 0.54) \times (1 - 0.01) \div 0.01)} = 2\%$$

$$\text{Negative predictive value} = \frac{0.54}{0.54 + ((1 - 0.98) \times 0.01 \div (1 - 0.01))} = 99.96\%$$

enough to make the clinician suspicious but not enough to make him certain. With a negative result there is a 49 in 50 chance (98%) of no malignant disease, providing a most useful piece of evidence.

The positive and negative predictive values depend upon sensitivity and specificity *and* upon the prevalence of the disease. Thus the predictive values calculated from any study will apply only in an environment with the same prevalence. Table III gives the formulae which are needed to calculate the positive and negative predictive values in an environment with a different prevalence. For example, in the report of Frankl and Ackerman (1977) 39% of the patients had breast cancer. How would the same test apply to a screening programme in which 1% of the patients presented with breast cancer? In this case the positive predictive value would decrease from 54% to 2% and the negative predictive value would increase from 98% to 99.96% (see Table III). The low positive predictive value would probably rule out such a test from a screening programme, although the extremely high negative predictive value is very desirable.

Receiver operating characteristic curves. In the preceding sections it was assumed that the result of the imaging technique must be negative or positive. However, for most techniques the results are not definitely positive or definitely negative; instead, graded levels of positivity can be distinguished. To define a summary measure such as sensitivity or specificity, the result must be arbitrarily converted into a dichotomy by choosing a cut-off point for positivity. All images falling on one side of the chosen level are then designated negative and all others positive. Naturally, investigators must carefully define their criteria for positivity to enable proper comparison of results. A typical problem of interpretation caused by the arbitrary choice of a cut-off point is shown in Table IV (Brion et al, 1985). The data indicate that CT has greater sensitivity than mediastinoscopy to mediastinal lymph node involvement, but less specificity. Which is the better test?

This problem may be avoided by defining a scale of positivity and reporting the distribution of scores on this scale for diseased and disease-free subjects. In the detection of mediastinal node involvement a natural scale of positivity would be the maximum diameter of lymph nodes seen on the scan. This would give rise to a continuous scale. More commonly the scale is chosen to be discrete, with 5 or 6 points, based on a subjective judgment of the confidence of the radiologist in the diagnosis (*e.g.* 1 = definitely negative, 2 = probably negative, 3 = possibly positive, 4 = probably positive, 5 = definitely positive (cf. Abrams et al, 1982)).

The ROC curve is constructed by considering, in turn, each point on the scale as the cut-off point for the definition of positivity and plotting the sensitivity against 1 minus specificity for each point. Some results

TABLE IV

COMPARISON OF CT AND MEDIASTINOSCOPY IN EVALUATION OF MEDIASTINAL LYMPH NODE INVOLVEMENT

Final staging at surgery	CT		Mediastinoscopy	
	No involvement	Involvement	No involvement	Involvement
No involvement	46	53	99	0
Involvement	6	48	18	36
	Sensitivity = 48/54 = 89%		Sensitivity = 36/54 = 67%	
	Specificity = 46/99 = 46%		Specificity = 99/99 = 100%	

Adapted from Brion et al (1985).

for CT and ultrasound for patients with suspected adrenal disease (Abrams et al, 1982) are shown in Fig. 1. A smooth curve has been drawn through the points on the basis of some statistical assumptions. When there is no predictive worth in the imaging technique the curve will tend to a straight line joining the origin with the top right hand of the graph. A perfect technique will be represented by a vertical line from the origin to the top left hand corner and a horizontal line from left to right at the top of the graph. The most commonly used summary of the ROC curve is the area under the curve, which will tend towards 0.5 for a useless technique and 1.0 for a perfect technique. The larger the area the more accurate is the technique and different techniques may be compared through the areas under their ROC curves.

However, this methodology has not yet gained wide acceptance. The meaning of the ROC curve is not easy to master: assigning a diagnostic image to one of the points of the scale is difficult and may vary considerably from one occasion to the next, even for the same radiologist. Furthermore, the area under the curve does not have the direct interpretation that is enjoyed by sensitivity or predictive value.

Numbers of patients

Studies of diagnostic accuracy conventionally include somewhere between 30 and 500 patients with a median figure of about 100. On the other hand there is almost never any mention in reports of the reasons for choosing the particular size adopted. The reason is probably that standard sample size methodology cannot be applied to these studies without the investigators specifying values for quantities of which they are largely uncertain.

The simplest way of determining sample size would be to ask how precise an estimate of the sensitivity and specificity of the technique are needed.

Table V shows the standard error of sensitivity (or specificity) achieved by a given number of diseased (or normal) patients. The standard error is affected by the level of sensitivity (or specificity) as well as the sample size and the table includes sensitivities ranging from 50% to 99%. An investigator may use this table in the following way. Firstly he should specify a few sample sizes which are within the bounds of practicality. Secondly he should ascertain the likely prevalence of disease in his study population and so calculate for each sample size the number of diseased and normal patients available for study. Thirdly he should make realistic guesses at the levels of sensitivity and specificity of the technique under evaluation. Finally, for each sample size he should read off the standard errors of sensitivity (using the number of diseased patients) and specificity (using the number of normals) from Table V, using interpolation where necessary, and consider whether they are inadequately large or unnecessarily small for the study. Investigators should demand smaller standard errors for sensitivities or specificities near the extremes of 0% and 100%; as a rule of thumb, standard errors should be less than half the difference between

TABLE V

STANDARD ERROR (%) of the estimate of sensitivity (or specificity)

No. of diseased (or normal) patients	Expected sensitivity (or specificity) (%)						
	50	70	80	90	95	98	99
25	10.0	9.2	8.0	6.0	4.4	2.8	2.0
50	7.1	6.5	5.7	4.2	3.1	2.0	1.4
75	5.8	5.3	4.6	3.5	2.5	1.6	1.1
100	5.0	4.6	4.0	3.0	2.2	1.4	1.0
150	4.1	3.7	3.3	2.4	1.8	1.1	0.8
200	3.5	3.2	2.8	2.1	1.5	1.0	0.7
300	2.9	2.6	2.3	1.7	1.3	0.8	0.6
500	2.2	2.0	1.8	1.3	1.0	0.6	0.4
1000	1.6	1.4	1.3	0.9	0.7	0.4	0.3

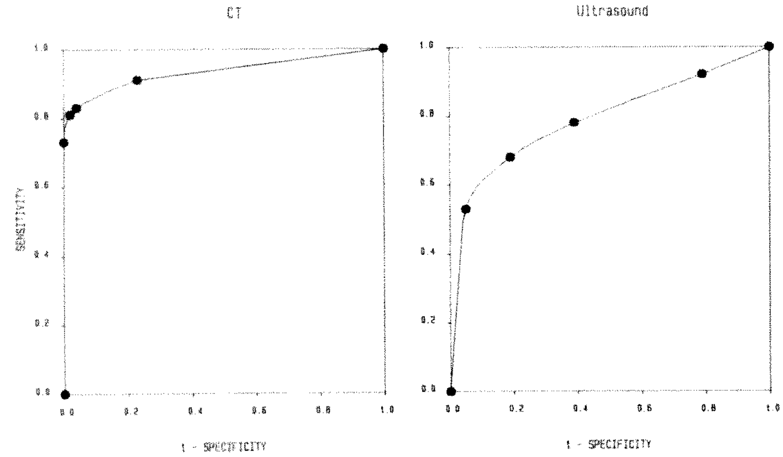


FIG. 1.

Adapted from Abrams et al (1982): ROC curves, comparing CT with ultrasound. Note the degree to which the CT curve moves to the upper left-hand corner of the graph, indicating greater diagnostic accuracy.

the expected sensitivity and the scale extremity (*e.g.* for a sensitivity of 95% the standard error should be less than 2.5% ((100%–95%)/2).

As an example of the use of Table V, suppose that an investigator wishes to conduct a study of the diagnostic accuracy of ultrasound in detecting metastases in the liver. A sensitivity of about 70% and a specificity of 90% are expected. The investigator thinks that he will be able to enter between 125 and 250 patients with suspected disease. The prevalence of the disease in the study group is expected to be about 40%, so between 50 and 100 patients with the disease could be entered. Table V shows him that 50 patients with the disease will yield a standard error of 6.5% for the sensitivity. The 95% confidence limits for the sensitivity will then equal the estimated sensitivity ±13% (*i.e.* 2 × 6.5%). If the investigator wishes to estimate the sensitivity more precisely, *e.g.* to within ±10%, he will need to enter between 75 patients (yielding ±2 × 5.3%) and 100 patients with disease (yielding ±2 × 4.6%).

The number of patients without disease is expected to be between 75 and 150. Table V shows that 150 patients without the disease will yield a standard error of 2.4% for a specificity of about 90%. This means the specificity will be estimated to within about ±5%. This may be the very largest error for specificity that the investigator could tolerate and he may therefore decide to enter a total of 250 patients in his study. If greater precision were required, the number of patients would have to be increased by lengthening the period of study or by extending the study to other hospitals. On occasion, studies may have to be abandoned because the number of available patients will be too few to give reasonably precise estimates of sensitivity and specificity.

Hanley and McNeil (1982, 1983) give formulae and tables for sample sizes of studies using ROC curve analysis.

Excluding "uninterpretable" test results

Husband et al (1977) report that 50 patients were examined by ultrasound and the pancreas visualised in 40 (80%). The measures of diagnostic accuracy described above do not take into account the proportion of "uninterpretable" test results. Harris (1981) notes that, unlike Husband et al, many authors may exclude results that are "inconclusive", do not have observer agreement, or that are associated with "technical" failure. He warns that this is a potential source of bias and that if results are to be excluded the criteria for exclusion should be specific and widely accepted. It is most important to report clearly the definition and the number of uninterpretable results for the imaging technique.

Summary of statistical points in the design of studies of diagnostic accuracy

(1) The imaging technique under evaluation should not influence the final diagnosis, directly or indirectly.

(2) The final diagnosis should, ideally, be based on autopsy or histological evidence, particularly in oncology.

(3) Patients selected for study should be as nearly representative of the target population as possible.

(4) The imaging technique should be performed and reported in a routine hospital service environment.

(5) To assist his diagnosis, the radiologist should be presented with clinical information in accordance with normal clinical practice.

(6) When comparing two or more techniques it is most economic (in terms of patient numbers) to assess each patient with each of the techniques in turn.

(7) If techniques are sometimes missed the investigators should consider the possible effect on their results.

(8) No imaging technique should be allowed to influence the performance of a competing technique.

(9) Predictive value is of more direct relevance to the performance of a test than sensitivity or specificity.

(10) Predictive value can change dramatically with an alteration in the prevalence of the disease.

(11) If there is a problem of interpretation which is partly or wholly caused by an arbitrary choice of cut-off point to separate negative from positive results, ROC curve analysis offers a possible solution.

(12) Numbers of patients should be chosen in relation to the standard errors required for estimating sensitivity or specificity.

(13) Uninterpretable test results should be reported.

Conclusions on studies of diagnostic accuracy

In the section on final diagnosis it was emphasised that the result of the imaging technique must be withheld from the clinician until the final diagnosis is obtained. Thus the design of the study requires that the imaging technique be assessed *out of clinical context*. There is no opportunity to assess at this stage how the technique will perform in combination with other diagnostic investigations nor how the clinician will use the information provided by the radiologist nor how the information will effect the performance of other investigations and treatment. It is quite clear that studies of diagnostic accuracy do not grapple with the full complexities of how an imaging technique contributes to the diagnostic and therapeutic process. As such they must be regarded as preliminary investigations. We return to this in Classification of Imaging Studies.

"CLINICAL VALUE" STUDIES

For a full evaluation of an imaging technique we need to enquire how it contributes to the diagnostic and therapeutic process in real-life conditions. This necessitates that, contrary to the diagnostic accuracy design, the result of the technique be reported directly to the clinician-in-charge. The evaluation may be split up into three components: how does the technique affect (1) diagnosis, (2) treatment and (3) patient outcome?

Studies of clinical value may be designed to address (1) or (2) or both. (Only randomised comparisons (see Assessment of Patient Outcome and Randomised Studies) can provide a direct answer to (3).) The essential feature in the design of studies of clinical value is that assessments are made firstly without the information contributed by the imaging technique and then again with that information. Figure 2, adapted from Wittenberg et al (1980), shows the design of their study to evaluate the efficacy of body CT. If a patient was eligible, the clinician was first asked to complete a form giving differential diagnostic probabilities and a provisional treatment plan as well as any contemplated additional diagnostic tests. Computed tomography was then performed and reported to the clinician, at which point he completed the form for a second time. At the time of the patient's discharge from hospital, the clinician completed the form for a third time and, in addition, gave a grading to the overall usefulness of CT in diagnostic understanding and choice of therapy. The carefully chosen scales for usefulness of CT are shown in Table VI.

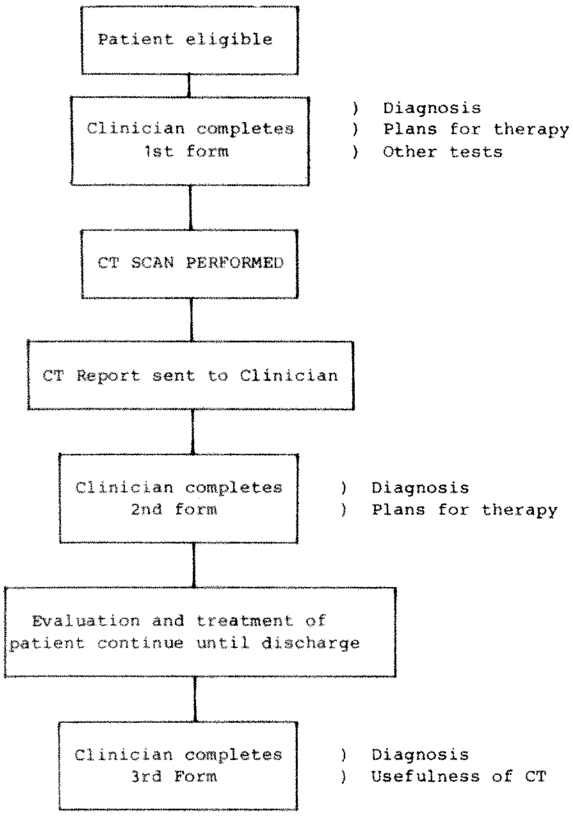

Patient eligible
Clinician completes 1st form
) Diagnosis
) Plans for therapy
) Other tests
CT SCAN PERFORMED
CT Report sent to Clinician
Clinician completes 2nd form
) Diagnosis
) Plans for therapy
Evaluation and treatment of patient continue until discharge
Clinician completes 3rd Form
) Diagnosis
) Usefulness of CT

FIG. 2.

Flow diagram of the design of a study of clinical value, adapted from Wittenberg et al (1980).

TABLE VI

SCALE FOR USEFULNESS OF CT

Diagnostic understanding

(1) CT confused my understanding of this patient's disease and led to investigations I would not otherwise have done
(2) CT confused my understanding of this patient's disease but did not lead to any additional investigations
(3) CT had little or no effect on my understanding of this patient's disease
(4) CT provided information which substantially improved my understanding of this patient's disease
(5) My understanding of this patient's disease depended upon diagnostic information provided only by CT (unavailable from any other non-surgical procedure)

Choice of therapy

(1) CT led me to choose therapy which in retrospect was not in the best interests of the patient
(2) CT was of no influence in my choice of therapy
(3) CT did not alter my choice of therapy but did increase my confidence in the choice
(4) CT contributed to a change in my chosen therapy but other factors (other imaging tests, other diagnostic tests, changes in patient status) were equally or more important
(5) CT was very important compared with other factors in leading to a beneficial change in therapy

Adapted from Wittenberg et al (1980).

The clinical value study design allows an evaluation of the contribution of an imaging technique within the clinical context. Issues such as the continuous scale of test results and the possibility of multiple diagnoses, which are difficult to accommodate in studies of diagnostic accuracy, are naturally incorporated into this design. A number of criticisms of the design can be made however.

Wittenberg et al (1980) recognise in their report that the results are based on the subject impressions of the participating clinicians. However, by recording opinions at three points during patient management they were able to check retrospectively on the consistency of the clinical course and the final assessment. They also note that the scale for choice of therapy may be insensitive to improvements in therapy, such as CT-guided percutaneous biopsies.

In oncology there has been particular interest in the effect of CT on precision rather than choice of treatment, with particular reference to CT-assisted radiotherapy planning. Several studies of this particular aspect of CT have been conducted and the design used by Prasad et al (1981) is typical. Firstly, routine diagnostic information was used to select a treatment plan with no CT result available. Then the treatment was replanned with the CT information. The plans were compared and it was decided whether the CT resulted in a modification of treatment. This design is another example of a study of clinical value, but here the limited objective of the study allows a more specific and objective measure of CT effect to be used. This avoids the criticism of subjectivity levelled against Wittenberg et al's design.

ASSESSMENT OF PATIENT OUTCOME AND RANDOMISED STUDIES

The benefits of a new imaging technique are excessively difficult to measure. Wittenberg et al's study and general experience suggests that CT is able to improve diagnostic understanding in many conditions, can avoid the performance of more invasive diagnostic tests, can give the clinician confidence in a treatment plan or suggest a change to a more beneficial treatment. These benefits may in themselves justify the expense of purchasing and running the new equipment but, in the presence of doubt about the relative costs and benefits, some information on the effect of a new technique on patient outcome would be welcome. However, reliable information about even the crudest measure of outcome, survival time, is nearly always absent from the cost–benefit equation. Two approaches to measure the effect of a diagnostic technique on patient outcome have been described.

Goitein (1979) has taken data from simulated studies of the effect of CT on radiotherapy planning and has fed these into a model to predict the clinical results of the increased precision of radiotherapy. The model is based upon an average dose–response relationship for the tumour and involves estimating the change in the probability of tumour control when part of the tumour is underdosed. With all the reservations that one must have over these extrapolations, Goitein estimates that CT improves the probability of local tumour control by an average of 6% and 5-year survival by 3.5%.

Goitein's approach represents an attempt to measure the effect of imaging on patient outcome in an *indirect* way, using the results of studies of clinical value which, by their nature, cannot provide a direct answer. The only type of study which can provide a *direct* answer is the randomised trial. The design requires that a patient is allocated to one of two alternative investigational policies. One policy will include the use of the new imaging technique, the other will not. By comparing the progress of the two groups of patients, the effects of the new technique on diagnosis, treatment, quality of life, response to treatment and length of survival may all be evaluated. Unfortunately, ethical and logistic problems abound and these trials have only rarely been attempted. Reid et al (1983) conducted a randomised trial of scintigraphy with and without tomography for 245 patients but restricted their analysis to effect on diagnosis. Dronfield et al (1977) compared endoscopy with radiology for 318 patients with acute upper gastrointestinal tract bleeding. Dixon et al (1981) compared CT with conventional imaging for 53 patients with an abdominal mass. While Dronfield et al detected no difference in management or survival, Dixon et al found that CT reduced the period of inpatient observation.

The ethical difficulties of randomised trials of imaging techniques appear to be greater than for trials of therapy. In most trials of therapy a new treatment is usually associated with potential benefit, but also with potential harm. Doubts over the harm allow the firm possibility that the current standard may be better than the new treatment and justify the ethics. Thus, disagreement over the reality of the hazard from multivitamins taken during pregnancy have led to arguments over the ethics of a Medical Research Council (MRC) trial (Anonymous, 1982). In imaging studies, the element of risk is usually considered to be minimal, otherwise the technique would not have reached the clinic. Thus, once a technique has shown promise in a diagnostic study it is difficult to deny its potential benefits to a patient.

The ethics of a randomised trial are justified if the new treatment is in short supply and available to only a limited number of patients, as in the pioneering MRC trial of streptomycin for pulmonary tuberculosis (MRC, 1948). There may also be occasions when an imaging technique is available to only limited numbers of patients. Could one then justify a randomised study by claiming that even outside the study many patients would not be able to benefit from the technique? From a practical point of view this argument would not usually hold, since once the technique is available in a hospital it would naturally be available for all patients in that hospital. One would therefore have to randomise hospitals rather than patients, a grand design but one which might prove unpopular!

A major practical problem for a randomised study is highlighted by Goitein's estimate of a 3.5% increase in 5-year survival from the use of CT in radiotherapy. To detect an increase of this order reliably would require tens of thousands of patients. Russell and Williams (1983) have extensively reviewed the problems awaiting the investigator who embarks on a randomised trial of imaging techniques.

In conclusion, the occasions when a randomised study is a feasible method of evaluating imaging techniques will be fairly rare. However, since it is theoretically the best method, its feasibility should always be considered at the design stage.

BEFORE-AND-AFTER STUDIES

The introduction of a new imaging technique into routine clinical use in a hospital affords an opportunity to study subsequent changes in diagnostic practice and results. While such studies are useful for monitoring changes in the use of diagnostic facilities, they are uncontrolled and as such are unreliable for drawing conclusions about the direct impact of a new technique. An example of the use of this study for monitoring is Dixon (1985), who investigated the practice of lymphography before, during and after the introduction of CT. He found a reduction in the number of lymphograms performed and considered the factors which may have been responsible, including the introduction of CT.

Appropriately the discussion section accounted for half the length of the article!

THE CLASSIFICATION OF CLINICAL TRIALS

Participants and organisers of research into therapeutic intervention have, over the years, developed a nomenclature for the various stages of investigation which may be required to introduce a new treatment (particularly a drug) into clinical practice. Table VII shows the four "phases" in chronological order, with brief definitions of each. Phase I trials are concerned with establishing a safe dose of the drug and the range and frequency of side-effects which are to be expected with that dose. Phase II trials aim to determine the efficacy of the drug in a quick and "preliminary" manner. In oncology this is done by selecting patients with measurable tumours and observing the change in size of tumour after treatment with the drug. Phase III trials are concerned with evaluating the use of the drug, possibly in combination with other therapies, in a clinical setting, and including a comparative group of patients chosen by randomisation to receive the standard therapy. Phase IV studies are concerned with monitoring the long-term effects of a therapy which has been newly adopted as routine treatment.

The above classification has been useful in sorting out the different possible investigations available and relating the appropriateness of a particular type of study to the aims of the research worker. The classification implies an order in which the questions relating to the drug should be tackled and a strategy, partly based on common sense, for providing answers to the questions. Thus, for example, Phase II trials which are relatively quick to perform, involving 15–50 patients, are a preliminary screening measure for the identification of the more promising therapies. For such therapies one may sensibly proceed to spend considerable resources in mounting a more complex Phase III study to try to establish the place of that therapy in routine practice. The existence of the classification therefore provides suitable advice to the investigator to avoid a difficult and expensive study without first obtaining good objective evidence of the worth of the treatment. At the same time it also provides a rein on the imagination of the enthusiastic investigator who would like to recommend his new treatment for routine use following a promising preliminary study. Thus, classifications are not simply convenient categorisations, but can influence the broad strategy of research.

TABLE VII

CLINICAL TRIALS CLASSIFICATION

Phase I	Toxicity, feasibility
Phase II	Screening for activity against disease
Phase III	Randomised controlled comparison in a clinical setting
Phase IV	Monitoring routine use and outcome

CLASSIFICATION OF IMAGING STUDIES

Table VIII shows a suggested classification of imaging studies which is somewhat analogous to the clinical trials classification. The "phases" correspond closely to the types of study outlined at the beginning of this paper, under Study Designs Employed to Evaluate Imaging Techniques.

Phase I incorporates pilot studies which assess the feasibility of a technique or make a very preliminary assessment of its promise.

Phase II corresponds to studies of diagnostic accuracy. These are placed early in the classification because, as has been explained, they assess the use of the imaging technique out of clinical context. While one might hope the results of diagnostic studies will transfer to clinical practice, this hope will often not be realised. The discovery by Wittenberg et al (1980) of a clinician's "learning curve" in the use of CT shows that transferral into clinical practice is not a simple matter. The experience with studies of carcino-embryonic antigen, which showed great promise in initial studies of diagnostic accuracy but turned out to be of very limited value in the clinic, underlines the general problem. The study of diagnostic accuracy cannot evaluate the imaging technique in the presence of other diagnostic tools. As such it is only a preliminary assessment of the technique. Nevertheless, nearly all investigators currently stop their evaluation at this stage of assessment.

Phase III comprises studies of the contribution of the technique to clinical management. Occasionally a randomised comparison will be possible, but usually the more feasible studies of clinical value should be the design of choice. Where the imaging technique affects treatment an attempt should be made to assess indirectly the consequent change in patient outcome, as done for CT.

Phase IV corresponds exactly to the monitoring of routine use of a newly introduced technique.

The analogy with the clinical trials classification is apt in the following sense. No clinician would wish to use a new drug in a full evaluation (Phase III) without good preliminary evidence of its activity against the disease (Phase II). The evidence gained from the Phase II study should be sufficiently encouraging to proceed to Phase III but will not guarantee success in that study.

TABLE VIII

CLASSIFICATION FOR IMAGING STUDIES

Phase I	Feasibility, promise
Phase II	Studies of diagnostic accuracy
Phase III	Studies of clinical value (*or* randomised comparisons where feasible) End-points: diagnosis, treatment, patient outcome
Phase IV	Before-and-after studies for monitoring routine use

Similarly the job of studies of diagnostic accuracy (Phase II) should be seen as furnishing preliminary evidence of an imaging technique's worth in an objective manner. The main test of the technique should then follow with a study of clinical value (Phase III). In this author's opinion, the major new effort in evaluation of imaging technique should be at the Phase III level, particularly in view of the increasing interest in expensive techniques such as MRI.

Finally, acknowledging on the one hand the difficulty and cost of running good diagnostic studies with large numbers of patients and, on the other hand, the increasing expense of diagnostic equipment and the consequent need for careful evaluation, it is worth considering a remark of McNeil et al (1981) in relation to one of their diagnostic studies: "We spent 17 months collecting data from two major teaching institutions. Full time research assistants at each institution tried to obtain all cases in random order. Yet even this concerted effort produced only 156 cases and then only 50% of them included objective proof of disease. Now is the time to think about the administration, organisation and financing of such studies."

ACKNOWLEDGMENTS

I would like to thank Dr D. Spiegelhalter, Dr I. Sutherland and Dr A. Dixon for stimulating discussions and advice, and Professor N. M. Bleehen for encouraging my interest in this topic. Constructive comments from a referee helped to clarify the message of this paper. The article is based on a review to be published in *Investigational Techniques in Radiation Oncology* (Springer-Verlag), 1987.

REFERENCES

ABRAMS, H. L., SIEGELMAN, S. S., ADAMS, D. F., SANDERS, R., FINBERG, H. J., HESSEL, S. J. & MCNEIL, B. J., 1982. Computed tomography versus ultrasound of the adrenal gland: a prospective study. *Radiology, 143,* 121–128.

ANONYMOUS, 1982. Vitamins to prevent neural tube defects. *Lancet, ii,* 1255–1256.

BRION, J. P., DEPAUW, L., KUHN, G., DE FRANCQUEN, P., FRIBERG, J., ROEMANS, P. & STRUYVEN, J., 1985. Role of computed tomography and mediastinoscopy in preoperative staging of lung carcinoma. *Journal of Computer Assisted Tomography, 9,* 480–484.

DIXON, A. K., 1985. The current practice of lymphography: a survey in the age of computed tomography. *Clinical Radiology, 36,* 287–290.

DIXON, A. K., FRY, I. K., KINGHAM, J. G. C., MCLEAN, A. M. & WHITE, F. E., 1981. Computed tomography in patients with an abdominal mass: effective and efficient? *Lancet, i,* 1199–1201.

DRONFIELD, M. W., MCILMURRAY, M. B., FERGUSON, R., ATKINSON, M. & LANGMAN, M. J. S., 1977. A prospective, randomised study of endoscopy and radiology in acute upper-gastrointestinal-tract bleeding. *Lancet, i,* 1167–1169.

FOSTER, P. N., MITCHELL, C. J., ROBERTSON, D. R. C., HAMILTON, I., IRVING, H., KELLEHER, J., LINTOTT, D. J., ROBINSON, P. J., AXON, A. T. R. & LOSOWSKY, M. S., 1984. Prospective comparison of three non-invasive tests for pancreatic disease. *British Medical Journal, 289,* 13–16.

FRANKL, G. & ACKERMAN, M., 1977. Xeromammography: five years and 559 carcinomas. *American Journal of Obstetrics and Gynecology, 29,* 61–64.

GOITEIN, M., 1979. The utility of computed tomography in radiation therapy: an estimate of outcome. *International Journal of Radiation Oncology, Biology, Physics, 5,* 1799–1807.

HANLEY, J. A. & MCNEIL, B. J., 1982. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology, 143,* 29–36.

——1983. A method of comparing the areas under ROC curves derived from the same cases. *Radiology, 148,* 839–843.

HARRIS, J. M., 1981. The hazards of bedside Bayes. *Journal of the American Medical Association, 246,* 2602–2605.

HAUSER, M. F. & GOTTSCHALK, A., 1978. A comparison of the Anger tomographic scanner and the 15 inch scintillation camera for gallium imaging. *Journal of Nuclear Medicine, 19,* 1074–1077.

HAWKES, R. C., HOLLAND, R. N., MOORE, W. S. & WORTHINGTON, B. S., 1980. NMR tomography of the brain: a preliminary clinical assessment with demonstration of pathology. *Journal of Computer Assisted Tomography, 4,* 577–586.

HUSBAND, J. E., MEIRE, H. B. & KREEL, L., 1977. Comparison of ultrasound and computer assisted tomography in pancreatic diagnosis. *British Journal of Radiology, 50,* 855–862.

MCNEIL, B. J., SANDERS, R., ALDERSON, P. O., HESSEL, S. J., FINBERG, H., SIEGELMAN, S. S., ADAMS, D. F. & ABRAMS, H. L., 1981. A prospective study of computed tomography, ultrasound and gallium imaging in patients with fever. *Radiology, 139,* 647–653.

MRC, 1948. Streptomycin treatment of pulmonary tuberculosis. *British Medical Journal, ii,* 769–782.

PRASAD, S. C., PILEPICH, M. V. & PEREZ, C. A., 1981. Contribution of CT to quantitative radiation therapy planning. *American Journal of Radiology, 136,* 123–128.

RANSHOFF, D. F. & FEINSTEIN, A. R., 1978. Problems of spectrum and bias in evaluating the efficacy of diagnostic tests. *New England Journal of Medicine, 299,* 926–930.

REID, A., DENDY, P. P., GEMMELL, H. G. & SMITH, F. W., 1983. Value of tomographic section views in identifying liver abnormalities by scintigraphy. *Acta Radiologica Diagnosis, 24,* 107–111.

RUSSELL, I. & WILLIAMS, A., 1983. Evaluation of computerized tomography: a review of research methods. In *Economic and Medical Evaluation of Health Care Technologies.* Ed. by A. J. Culyer & B. Horisberger (Springer-Verlag, Berlin), pp. 298–379.

SHARP, P. F., DENDY, P. P. & KEYS, W. I., 1985. *Radionuclide Imaging Techniques,* Chapter 9 (Academic Press, New York.)

WITTENBERG, J., FINEBERG, H. V., FERRUCCI, J. T., SIMEONE, J. F., MUELLER, P. R., VAN SONNENBERG, E. & KIRKPATRICK, R., 1980. Clinical efficacy of computed body tomography, II. *American Journal of Roentgenology, 134,* 1111–1120.

Book reviews

Diagnostic Imaging in Neurological Disease. By Ivan Moseley, pp. x+283, 1986 (Churchill Livingstone, Edinburgh), £55.00. ISBN 0-443-03619-5

The introduction and increasing availability of new non-invasive methods of imaging has exacerbated the inappropriate use of diagnostic tests. The investigation of patients with neurological disease is no exception. The prospective reader should know that this is not yet another textbook of neuroradiology (spare the thought) but a book about the appropriate and economic use of diagnostic imaging for the investigation of patients with neurological problems. The author's aim is to indicate to all those who see such patients, not what tests can be done and what they show, but what ought to be done.

In an introductory chapter in which the factors which should govern the choice of imaging are considered, such as the information required and the effect on management, pride of place is given to the wishes of the patient, an interesting and refreshing approach. There are, in addition, useful sections on imaging in pregnancy, and on consent. The next four chapters are devoted to the non-invasive and invasive methods currently available to image the skull, axial skeleton, the orbits and the central nervous system. The physical basis of the method, the effect on the patient and the materials required are all discussed, as is cost, a factor in the equation which radiologists and clinicians in this country must increasingly heed. In the second half of the book the author considers how these tests should be used to establish the cause of the patient's disability, taking as a starting point the symptoms and signs as elicited by a specialist neurological physician. This logical approach enhances the practical value of the book, as does the summary of the author's principal recommendations under each heading. At the end of each chapter there is a generous list of references, rather more than 900 in all, the most recent to publications which appeared in 1984. The illustrations are of high quality and of sufficient number to reinforce the message of the text.

It will be evident to all that the author has extensive experience and a deep understanding of the role of imaging in neurological disease and his opinions and recommendations reflect this in full measure.

The reader is successfully guided (goaded perhaps) through the labyrinth of imaging methods now available and with a merciless logic the author shows that many cherished opinions are merely shibboleths and some firmly held beliefs have insecure foundations. His opinions are spiced by trenchant comment which serves to make the reader sit up and take notice and will no doubt ruffle a few feathers as well. There is little one would wish to add to the text or with which to disagree. Some may see a certain bias in the way the evidence is marshalled but one should be indulgent as the author is on the side of the angels.

I greatly enjoyed reading this timely publication written in a lucid, literary style mercifully free of "state-of-the-art" and seldom marred by "modality". The author succeeds in getting his message across in an enlightening informative and entertaining manner, all hallmarks of a good teacher. Every radiology department with a responsibility for the investigation of patients with neurological disease should possess a copy of this book and, were it not so expensive, purchase a second copy to be sent as a gift and long-term investment to clinical colleagues.

T. D. Hawkins

Diagnostic Imaging in Surgery. By Ronald L. Eisenberg, pp. xxiv+834, 1987 (McGraw-Hill, New York), £135.00. ISBN 0-07-019309-6

This book is intended to complement Schwartz's *Principles of Surgery*. The organisation and subheadings of this popular American surgical text are followed as clearly as possible in this radiological counterpart.

Although aimed at surgeons, *Diagnostic Imaging in Surgery* is also intended as a reference book for radiologists. It is therefore appropriate to consider how far this book satisfies the requirement of both specialties. The radiological appearances are described in a huge range of conditions, encompassing all body systems and including a large number of essentially medical diseases. In fact, the book falls just short of being a general textbook of radiology, only prevented by the exclusion of other non-surgical conditions and by the limited description of differential diagnoses. There is an imbalance in this book. For instance, aspects of fetal ultrasound are described and there is a discourse on the radiological appearances of such esoteric conditions as cretinism and pseudohypoparathyroidism. On the other hand, there is no specific mention of colonic angiodysplasia as an important cause of intestinal bleeding and no description of how to investigate congenital tracheobronchial fistula but the radiologist will find that post-operative appearances and trauma in general are well covered.

Would this textbook find favour with surgeons? Some description of plain radiographic appearances would surely be relevant, especially in regard to trauma and the acute abdomen, where the surgeon may interpret the radiographs. These aspects are generally well covered. A problem-orientated approach, with clear descriptions of diagnostic pathways, a comparison between various imaging and other diagnostic techniques, together with an evaluation of the hazards and advantages of various imaging modalities would seem to be reasonable inclusions in a textbook on imaging which is tailored for the surgeon. These aspects are not consistently covered and, when present, tend to be smothered by a welter of descriptive radiology.

The illustrations are generally of a high standard, many being taken from original articles. Key references are given at the end of each chapter but it is slightly annoying that figures are not referred to in the text.

In summary, this substantial and expensive textbook falls between two stools in that it does not altogether satisfy the needs of the surgeon or the radiologist. This is unfortunate, since the production is of a high standard and its compilation must represent an enormous effort on the part of the author.

G. H. Whitehouse

1987, *The British Journal of Radiology*, *60*, 1083–1088

NOVEMBER 1987

The accuracy of digital subtraction angiography for the quantification of atherosclerosis

By H. Key, M.Sc., P. C. Jackson, Ph.D., *E. A. Thomas, M.R.C.P., *W. D. Jeans, F.R.C.R. and *E. R. Davies, F.R.C.R.

Department of Medical Physics, Bristol General Hospital, Bristol BS1 6SY and *Department of Radiodiagnosis, Bristol Royal Infirmary, Bristol BS2 8HW

(*Received December 1986 and in revised form February 1987*)

ABSTRACT

Digital subtraction angiography (DSA) allows the degree of arterial patency or stenosis to be rapidly quantified. We have assessed the accuracy with which a single-plane DSA system is able to quantify area patency by densitometric and geometric methods. Arterial phantoms were designed to test for systematic error; intra-arterial DSA images of critical lesions of the carotid bifurcation and the lower abdominal and peripheral vessels were used to determine intra- and interobserver reproducibility. The densitometric method, which was more accurate than the geometric method, had a mean systematic error of up to 4% and a mean intra-observer variability of about 15% (coefficient of variation). We have identified the principal sources of inaccuracy and ways in which it may be reduced.

Angiography provides a morphological description of the disease process in patients with atherosclerosis, and as part of this description it is sometimes useful to determine the degree of vessel stenosis or patency. In particular, the recent advances in percutaneous transluminal angioplasty have stimulated the development of quick and accurate measurement techniques by digital subtraction angiography (DSA) that allow the vessel patency to be determined before and after treatment. We have studied the accuracy and limitations of two methods for quantifying arterial patency which are supplied as standard software with a commercial DSA system.

MATERIALS AND METHODS

A Quantel IDIS unit was used for the acquisition and analysis of images. The unit digitises the output of a standard fluoroscopic video camera and records the digital images onto a high-speed Winchester disk at a maximum rate of 2.78 frames/s. The recorded image sequence may immediately be replayed in subtracted form, and would normally be processed by temporal averaging and/or spatial filtering. The signal-to-noise ratio of recorded images is principally determined by the fluoroscopic exposure rate: we used an intensifier input exposure rate of 90 μR/s, which corresponds to an air kerma value of 0.3 μGy/frame. The spatial resolution of images is set by the 512×512 digital display matrix: the limiting resolution is about 1.2 line pairs per mm with a 21 cm intensifier input field size.

The patency of a diseased vessel is defined as the minimum cross-sectional area at the lesion expressed as a percentage of the normal area. We evaluated the accuracy with which patency could be measured in DSA: systematic error was assessed using a DSA phantom, and reproducibility (precision) was determined from patients' images.

Quantification methods

As the first stage in the measurement procedure, the operator positions two line segments (each of single pixel width) across the image of the diseased vessel, one at the critical stenosis and the other across the nearest portion judged to be normal. From intensity profiles along the two segments (Fig. 1) the operator must then select the vessel edges: on the basis of these limits the area patency is calculated geometrically and densitometrically. The geometric method is simply to assume that the vessel has circular cross-sections at the two chosen points. The densitometric method (Kruger, 1981; Seibert et al, 1985) is to take the integrated signal intensity between the vessel limits as proportional to the vessel area at that place. This is based upon the fact that logarithmic amplification followed by subtraction generates a signal intensity across an artery cross-section given by

$$D(x) = \mu c d(x) \tag{1}$$

where $D(x)$ is the difference signal, μ is the effective mass attenuation coefficient of iodine, c is the iodine concentration, and $d(x)$ is the projected thickness of the iodinated region. For a calibrated system, summing $D(x)$ across a vessel diameter yields the cross-sectional area, A:

$$A = \frac{\Sigma_i D(x_i)\Delta x}{\mu c M} \tag{2}$$

where M is the magnification of the vessel at the image intensifier and Δx is the pixel width in the digital image. The patency of a diseased vessel is given by

$$\frac{A_1}{A_2} \times 100\% = \frac{\Sigma_i D_1(x_i)}{\Sigma_i D_2(x_i)} \times 100\% \tag{3}$$

provided that the iodine concentration is the same at the normal and stenotic portions of the vessel (areas A_2 and A_1 respectively).

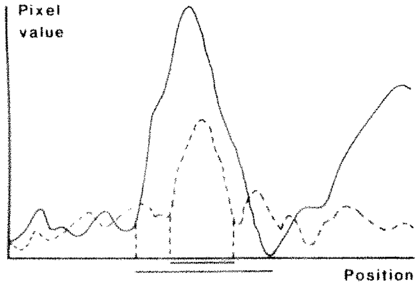


FIG. 1.

Intensity profiles across a normal portion (solid curve) and an atherosclerotic portion (dashed curve) of a vessel.

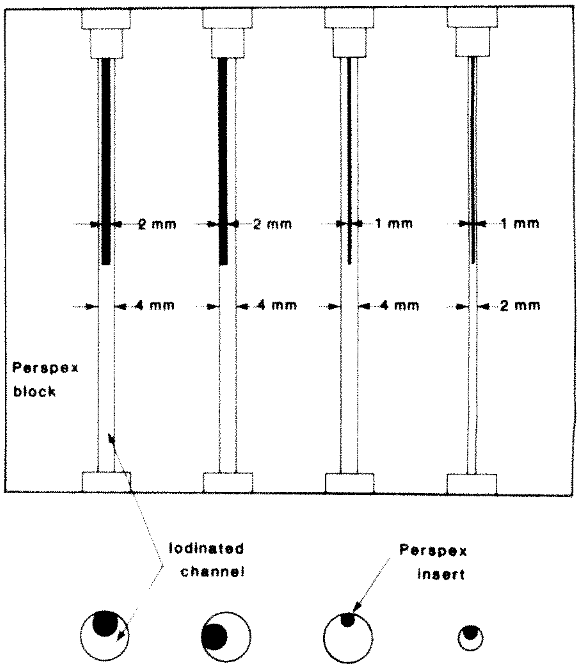


FIG. 2.

Stenosis phantom used to identify systematic error. A plan view (above) and a magnified (×2) cross-sectional view (below) are shown.

Assessment of systematic error

Systematic error arising from observer and instrument bias can be identified if the true value of a measurement is known. A subtraction phantom was designed which incorporated iodinated "vessels" with known reductions in luminal cross-sectional area (Fig. 2). Circular-section channels in a Perspex block were filled with a non-ionic contrast medium at an iodine concentration of 50 mg/ml. The channels were partially restricted at one end by Perspex inserts of various sizes and orientations, in an attempt to model the way in which atheromatous plaque accumulates on an artery wall. The channels of a mask block, manufactured to the same specification, were filled with saline solution. Images were acquired with 5 cm blocks of Perspex above and below the phantoms to simulate scattering in soft tissue.

Patency measurements were made on phantom images which had been processed by "integration" of four mask frames and four iodinated frames. This procedure is similar to that used in routine DSA and has the effect of improving the noise characteristics of the image. Each observer made a complete set of measurements on nine occasions, and the average measurements were compared with the true values to determine systematic error. Three observers took part in the study, which was conducted over a 6-week period with an interval of at least 3 days between measurements.

In connection with the densitometric technique, the system linearity (Equation (1)) was checked experimentally. Mean pixel value in a region of interest was studied as a function of iodine concentration in one of the phantom channels.

Assessment of reproducibility

Images from 23 patients with critical stenoses were used to investigate reproducibility. The images were selected randomly, without regard to image quality or to the ease with which vessel patency could be measured. There were 11 views of the extracerebral carotid vessels, visualised by selective arterial injection, and 12 views of the lower abdominal and peripheral vessels, visualised by injection into the lumbar aorta. The injected concentrations of contrast medium were usually 190 mg I/ml in carotid studies and 240 or 300 mg I/ml in aortography. The images had been processed by single-frame remasking (three images), matched temporal filtration (six images), or by frame integration (14 images). Each of the three observers made independent measurements of vessel patency on four occasions, with an interval of 1 week between consecutive measurements.

RESULTS

Systematic error

Measurements on the DSA phantom (Table I) indicated that the three observers tended to overestimate the patency when using the geometric method and slightly underestimate when using the densitometric method: systematic errors generally fell within the ranges 10–20% and −4–0% respectively. The bias did not vary much between the three observers. It is seen that the error in the geometric estimation was dependent upon the orientation of the eccentric obstruction (compare Vessel 1 with Vessel 2, Table I); the error in the densitometric method was independent of orientation.

The imaging system was found to respond linearly up to a projected iodine concentration of 60 mg/ml, which is above the normal DSA range. This suggests

TABLE I

Systematic error associated with patency measurements made on phantom images by observers A, B, and C

Vessel no.	Patency (%)	Mean error* ± SE		
		A	B	C
Geometric method				
1	75	16±5	12±7	17±6
2	75	19±6	21±4	27±8
3	94	6±6	−2±6	10±7
4	75	13±9	9±13	14±8
Densitometric method				
1	75	−2±3	−3±4	−2±3
2	75	−5±5	−2±3	−4±2
3	94	−3±4	1±4	−3±2
4	75	−1±6	3±10	−2±5

*Mean measured value − actual value.

that non-linearity will not be a source of systematic error in densitometric measurements.

Intra-observer reproducibility

The 23 images generated a wide spread of standard deviations associated with measurements made by each observer. Coefficients of variation (CVs), which express standard deviation as a percentage of the mean, were used to assemble the data into average figures for intra-observer variability (Table II). The use of average CV was justified by establishing that there was no significant correlation between CV and vessel patency: linear correlation coefficients for the six sets of data were all less than 0.2 ($p > 0.4$). The mean patency of the 23 vessels was given as 36% by the geometric method and as 31% by the densitometric method.

Table II shows that the intra-observer variability was not significantly dependent upon the observer or upon the vessel site. Average CVs were in the range 19–20% for the geometric method and 14–16% for the densitometric method.

TABLE II

Intra-observer variability associated with percentage patency measurements made by observers A, B and C

Vessel site	Mean coefficient of variation (%) ± SE		
	A	B	C
Geometric method			
Overall	19±2	20±2	19±3
Carotid bifurcation	21±3	21±4	18±3
Lower abdominal and peripheral vessels	17±3	20±3	20±5
Densitometric method			
Overall	16±2	15±2	14±2
Carotid bifurcation	17±3	17±4	12±3
Lower abdominal and peripheral vessels	15±2	13±2	15±3

TABLE III

Interobserver variability associated with percentage patency measurements

	Mean standard deviation ± SE	
	Geometric method	Densitometric method
Carotid bifurcation	7±2	4±1
Lower abdominal and peripheral vessels	5±1	3±1

There did not appear to be any change in mean values and intra-observer precision as the observers become more familiar with the techniques and with the set of images: no correlation was found between patency measurements and the occasion on which observations were made.

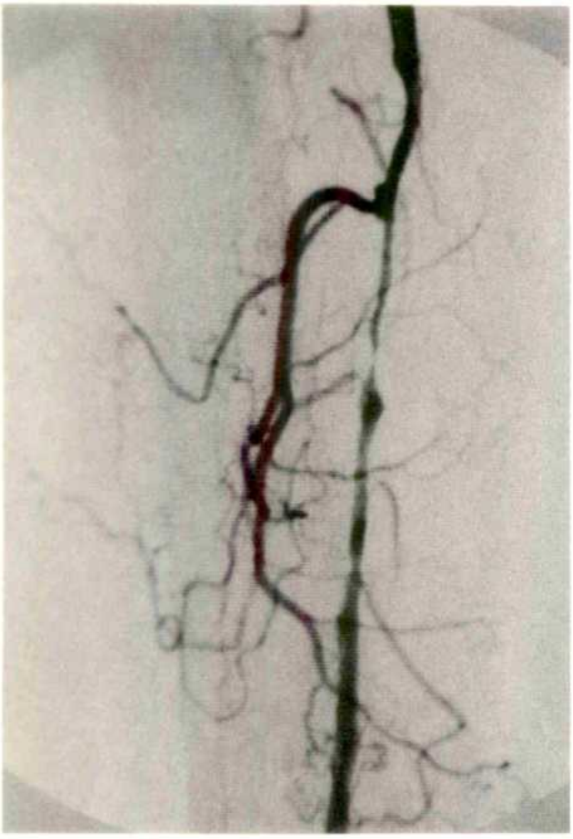
Interobserver reproducibility

Interobserver variability has a random component which derives from the intra-observer variations and a non-random component which derives from differences in systematic errors. The second component can be made predominant by averaging over a large number of measurements for each observer. Table III indicates the extent of non-random interobserver reproducibility. The use of average CVs was not justified in this case because significant correlations were detected between CV and mean patency measurement.

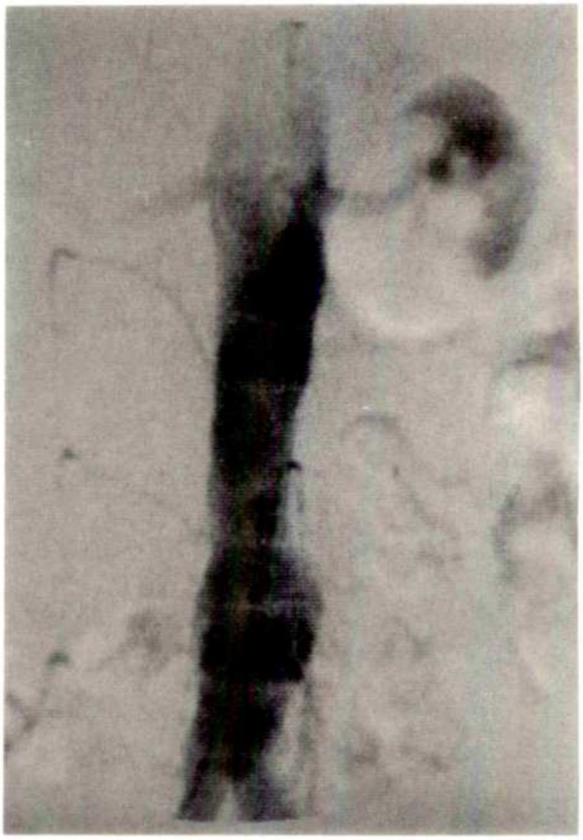
On average, the densitometric method generated less observer variation than the geometric method (see Table III). Analysis of the raw data also revealed that in almost all of the 23 studies the standard deviation for non-random interobserver variability was less than the standard deviations for intra-observer variability.

Discussion

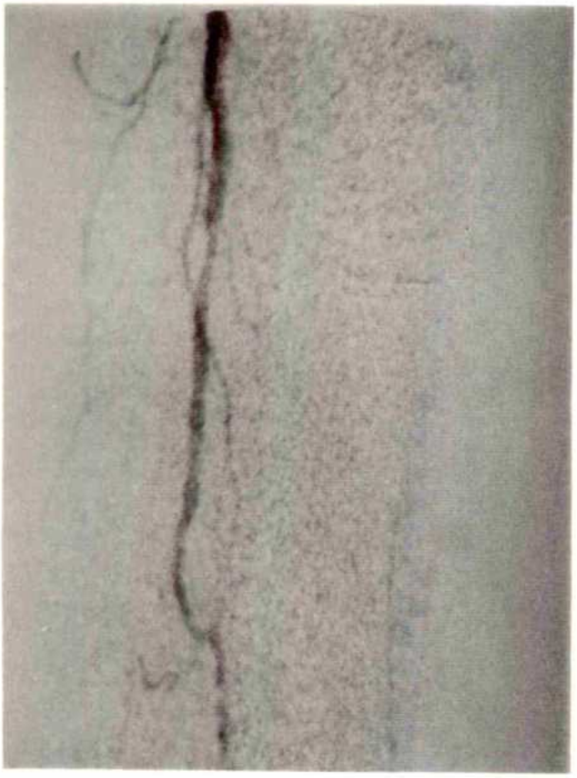
Accurate quantification of arterial stenosis is important for the proper management of patients suffering from aorto-iliac and carotid bifurcation atherosclerosis. Flow and pressure measurements are commonly used to assess haemodynamically significant disease: flow may be determined using electromagnetic probes or Doppler ultrasound methods (Strandness, 1986); pressure measurements may be made directly using arterial cannulae or indirectly using occlusion cuffs, with or without vasodilatation (Gunn et al, 1981; Williams & Flanigan, 1984; Baker et al, 1985). Arteriography has also been used to provide haemodynamic information (Itzchak et al, 1975; Bateman & Kruger, 1984), but it is primarily a morphological study of the disease process. In particular, it is able to estimate the reduction in vessel diameter or cross-sectional area caused by atheromatous plaque; an area reduction of 70–80% is



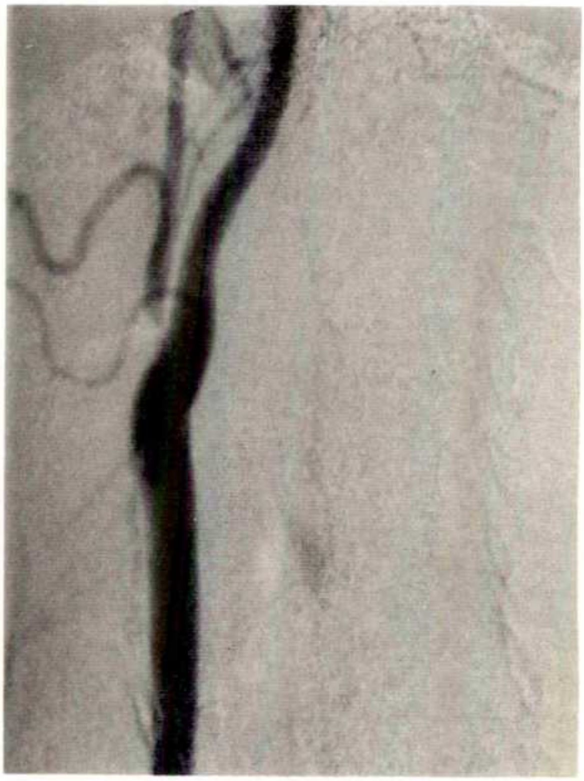
A



B



C



D

often found to be haemodynamically "critical" (Berguer & Hwang, 1974). Quantification of arterial patency is possible using conventional angiography but has been made faster and more accurate by the introduction of DSA.

Geometric method

If the arterial diameter patency or stenosis is measured from conventional radiographs the intra- and interobserver reproducibility is poor (DeRouen et al, 1977; Blankenhorn & Curry, 1982). In our study of DSA methods, it has been possible to increase the precision with which vessel edges are located, although better results have been reported (Reiber, 1985) for systems with computerised edge-tracking facilities.

The major weakness inherent in all geometric methods is that atheromatous plaque tends to develop eccentrically, so that multiplane projections are necessary for proper assessment of critical diameter and area reduction (Thiele & Strandness, 1983; Simons & Kruger, 1985).

Densitometric method

We have found that the more accurate measurement of arterial area patency was usually obtained densitometrically. This measurement can be made from a single projection and without knowledge of the vessel cross-sectional shape. It is better suited to DSA than to film angiography because it takes advantage of good contrast resolution while not being limited by poor spatial resolution.

Systematic error is introduced into measurements if image profiles are drawn across regions in which the background intensity is not zero. Motion artefact should thus be avoided by restricting patient movement and by prudent selection of images; the problem of overlapping iodinated vessels (Fig. 3A) is reduced with selective arterial injections, but it may, nevertheless, be necessary to acquire more than one view of the lesion. Error due to unequal concentrations of contrast medium at the two profiles can be minimised by making smooth injections with a pump, combined with careful image processing and selection of a normal vessel segment as close as possible to the site of the critical lesion. The latter will also reduce inaccuracy arising from X-ray scatter and image-intensifier veiling glare (Nalcioglu et al, 1982). Our experiments with phantoms indicated that no significant departure from linearity was introduced by beam hardening in different iodine thicknesses (Harrison, 1985).

Intra-observer variability determined in the way we have described has two components: one derives principally from the subjective visual choice of critical and normal vessel sites; the other is due to the inherent image noise (Wright et al, 1985). The former will be predominant in cases of diffuse atherosclerosis (Fig. 3B), in which neither the critical site nor a normal site is easily identified. The primary component of image noise is described by quantum statistics of the X-ray fluence and can thus be reduced by acquiring DSA images at the highest fluoroscopic exposure rate (Fig. 3C). Further improvement in image signal-to-noise ratios can be made by temporal averaging methods ("integration" or "matched temporal filtration"); spatial averaging ("smoothing") will be beneficial provided that it does not impair accurate location of the site of the critical lesion. Finally, repeated measurements should be made on an image, the observer positioning new segments on each occasion. In the absence of systematic error, if the imprecision of patency measurements (expressed as standard error of a mean) is reduced to 2.5% then a 70% lesion will be distinguishable from an 80% lesion with 95% confidence: our study indicates that this could be achieved by a noise reduction of less than two fold.

CONCLUSIONS

Variability and systematic errors are both smaller when arterial patency is measured using a DSA densitometric technique rather than geometrically. Adequate accuracy is normally achievable if image aquisition, processing and data extraction are performed in the manner described.

Further work is necessary to describe the validity of using angiographic measurements to predict clinical and haemodynamic effects. Discrepancies between morphological and haemodynamic parameters are particularly likely to arise when collateral pathways develop or when several severe stenoses are present in series.

REFERENCES

BAKER, A. R., PRYTHERCH, D. R., EVANS, D. H. & BELL, P. R. F., 1985. Characterisation of aorto-iliac arterial stenoses in terms of pressure and flow. *Cardiovascular Research, 19*, 559–566.

BATEMAN, W. A. & KRUGER, R. A., 1984. Blood flow measurement using digital angiography and parametric imaging. *Medical Physics, 11*, 153–157.

BERGUER, R. & HWANG, N. H. C., 1974. Critical arterial stenosis: a theoretical and experimental solution. *Annals of Surgery, 180*, 39–50.

BLANKENHORN, D. H. & CURRY, P. J., 1982. The accuracy of arteriography and ultrasound imaging for atherosclerosis measurement. *Archives of Pathology and Laboratory Medicine, 106*, 483–489.

DEROUEN, T. A., MURRAY, J. A. & OWEN, W., 1977. Variability in the analysis of coronary arteriograms. *Circulation, 55*, 324–328.

FIG. 3.

Circumstances which make for inaccurate measurements. (A) Overlapping iodinated vessels: this is particularly a problem in intravenous angiography. (B) Diffuse atherosclerosis. (C) High noise levels. (D) Critical narrowing occurs very close to the vessel branch point.

Gunn, I. G., Cowie, T. N., Forrest, H., Quin, R. O., Sheldon, C. & Vallance, R., 1981. Haemodynamic assessment following iliac artery dilatation. *British Journal of Surgery*, *68*, 858–860.

Harrison, R. M., 1985. A note on beam hardening in iodine-subtraction imaging and its implications for quantitative measurements. *Physics in Medicine and Biology*, *30*, 1335–1341.

Itzchak, Y., Yerushalmi, S. & Deutsch, V., 1975. Blood flow measurements in the iliac arteries by an improved angiographic cinedensitometric technique. *Investigative Radiology*, *10*, 1–9.

Kruger, R. A., 1981. Estimation of the diameter of and iodine concentration within blood vessels using digital radiography devices. *Medical Physics*, *8*, 652–658.

Nalcioglu, O., Seibert, J. A. & Roeck, W. W., 1982. Requirements for and capabilities of X-ray video systems to provide quantitative information. *Society of Photo-optical Instrumentation Engineers*, *318*, 445–453.

Reiber, J. H. C., 1985. Taking a quantitative approach to cine angiogram analysis. *Diagnostic Imaging*, *7*, 87–89.

Seibert, J. A., Link, D. P., Hines, H. H. & Baltaxe, H. A., 1985. Videodensitometric quantitation of stenosis: in vitro and in vivo validation. *Radiology*, *157*, 807–811.

Simons, M. A. & Kruger, R. A., 1985. Vessel diameter measurement using digital subtraction radiography. *Investigative Radiology*, *20*, 510–516.

Strandness, D. E., 1986. Ultrasound in the study of atherosclerosis. *Ultrasound in Medicine and Biology*, *12*, 453–464.

Thiele, B. L. & Strandness, D. E., 1983. Accuracy of angiographic quantification of peripheral atherosclerosis. *Progress in Cardiovascular Diseases*, *26*, 223–236.

Williams, L. R. & Flanigan, D. P., 1984. Alterations in femoral artery haemodynamics associated with femoro-popliteal bypass. *Journal of Surgical Research*, *36*, 97–101.

Wright, G. A., Taylor, K. W. & Rowlands, J. A., 1985. Noise in stenosis measurements using digital subtraction angiography. *Medical Physics*, *12*, 705–712.

1987, *The British Journal of Radiology*, 60, 1089–1092 NOVEMBER 1987

The role of technetium-99m pentavalent DMSA in the management of patients with medullary carcinoma of the thyroid

By *Susan E. M. Clarke, M.Sc., M.R.C.P., Colin Lazarus, Ph.D., Raman Mistry and Michael N. Maisey, M.D., F.R.C.P., F.R.C.R.

Department of Nuclear Medicine, Guy's Hospital, London SE1

(*Received November 1986 and in revised form March 1987*)

ABSTRACT

In order to assess the role of $^{99}Tc^{m}$ pentavalent dimercaptosuccinic acid ($^{99}Tc^{m}$ (V)DMSA) scanning in the management of patients with medullary carcinoma of the thyroid, we imaged 10 patients with histologically proven disease. Nine of the 10 patients were scanned after removal of the primary tumour, but with symptomatic or biochemical evidence of recurrence. One patient was imaged prior to thyroidectomy. In eight of the 10 patients $^{99}Tc^{m}$(V)DMSA successfully identified tumour deposits, and it has been shown in this study to be a cheap, convenient radiopharmaceutical for studying this group of patients, producing high-quality images with low radiation doses, and contributing significantly to patient management.

Medullary carcinoma of the thyroid (MCT) is an uncommon tumour accounting for less than 12% of all thyroid malignancies. Like follicular carcinomas of the thyroid, however, patients may survive a significant number of years following initial diagnosis, and the incidence of recurrent disease in this group is high (Keiser et al, 1973). At present, treatment is limited to surgical removal of the primary tumour and local radiotherapy to recurrent tumour, although several chemotherapy trials are currently in progress. The carcinoma metastasises to bone and liver, with secondary deposits also observed in the lungs and brain. Recurrence is suspected when the plasma calcitonin level becomes elevated, although biochemical evidence of recurrence may precede clinical evidence of recurrence by many years. Various imaging techniques have been used to follow these patients, including $^{99}Tc^{m}$ methylenediphosphonate (MDP) bone scanning, $^{99}Tc^{m}$ colloid liver scanning, conventional radiology, liver ultrasound and computed tomography (CT). A group of Japanese workers (Yokoyama et al, 1981; Ohta et al, 1984a) has developed $^{99}Tc^{m}$(V)DMSA as a head and neck tumour-imaging agent, and following their report of uptake in individuals with primary and recurrent MCT (Ohta et al, 1984b) we studied 10 patients with histologically proven MCT and biochemical or symptomatic evidence of recurrence, to assess the role of $^{99}Tc^{m}$(V)DMSA in the management of patients with MCT.

PATIENTS AND METHODS

Ten patients were studied, seven female and three male, age range 14–74 (mean 49.1) years. One was imaged prior to surgery for the primary tumour, eight had biochemical evidence of recurrence (*i.e.* calcitonin levels elevated above 100 pg/ml) and one had symptoms suggestive of recurrence. Two patients were imaged before and after surgery for local recurrence in the neck. Table 1 outlines the details of each patient.

Radionuclide imaging

The $^{99}Tc^{m}$(V)DMSA was prepared using a modification of technique outlined by Ohta et al (1984a) and Sampson (1987). 4.4 mg DMSA, 120 mg dextrose and 5.04 mg sodium bicarbonate were added to an Amersham DMSA vial. These powders were dissolved in 0.4 ml of 7% sodium bicarbonate solution and 0.1 ml of this solution was added to 2.5 ml $^{99}Tc^{m}$ pertechnetate containing 600 MBq (16 mCi) of activity. The injection was filtered through a 0.22 μm filter before use. Each patient was then injected intravenously with 370 MBq (10 mCi) $^{99}Tc^{m}$(V)DMSA, and whole-body images were acquired 2 h later using a gamma camera with a large field of view and a dedicated processor. Areas of uptake were evaluated with conventional radiology, CT and $^{99}Tc^{m}$ MDP bone scans.

RESULTS

Nine of the 10 patients had elevated calcitonin levels. One patient, discovered on screening of first-degree relatives to have an elevated calcitonin level, was imaged before surgery to the primary tumour and uptake of $^{99}Tc^{m}$(V)DMSA was observed in the right lobe of the thyroid. Eight patients had uptake of $^{99}Tc^{m}$(V)DMSA at sites proven with other imaging techniques to be of recurrent tumour and five of these also had histological evidence of recurrence. Two of the eight had evidence of local recurrence in the neck and underwent surgery to remove involved nodes. Post-surgical imaging with $^{99}Tc^{m}$(V)DMSA in one patient showed complete clearance of tumour, but a small amount of residual activity was present in the site of recurrence in the other patient, who subsequently had

---

*Author for correspondence.

TABLE I

PATIENT DETAILS

Case No.	Age (years)	Sex	Calcitonin levels (pg/ml normal = < 100)	Symptoms	Evidence for tumour
1	39	F	<100	+	CT negative
2	65	M	6100	+	CT positive Bone scan positive
3	52	F	8970	+	CT positive Bone scan positive
4	45	M	6000	+	CT positive Bone scan positive
5	38	F	995	—	CT negative Bone scan negative
6	74	F	5310	+	CT positive Bone scan positive
7	53	M	3540	+	CT positive Bone scan negative
8	52	F	2400	+	CT positive Bone scan negative
9	24	F	1200	—	CT positive Bone scan negative
10	14	F	400	—	Confirmed surgically

local radiotherapy to this site (Fig. 1). One patient with known recurrence in the neck also complained of epigastric discomfort, and $^{99}Tc^{m}$(V)DMSA demonstrated tumour in the neck and an unsuspected secondary deposit in the left lobe of the liver. In four patients, $^{99}Tc^{m}$(V)DMSA clearly demonstrated the extent of the recurrent disease, visualising both bone and soft-tissue metastases, including liver (Fig. 2) and skin secondaries.

Two patients showed no abnormal uptake of $^{99}Tc^{m}$(V)DMSA when imaged. One of these was a patient in whom the primary tumour had been removed

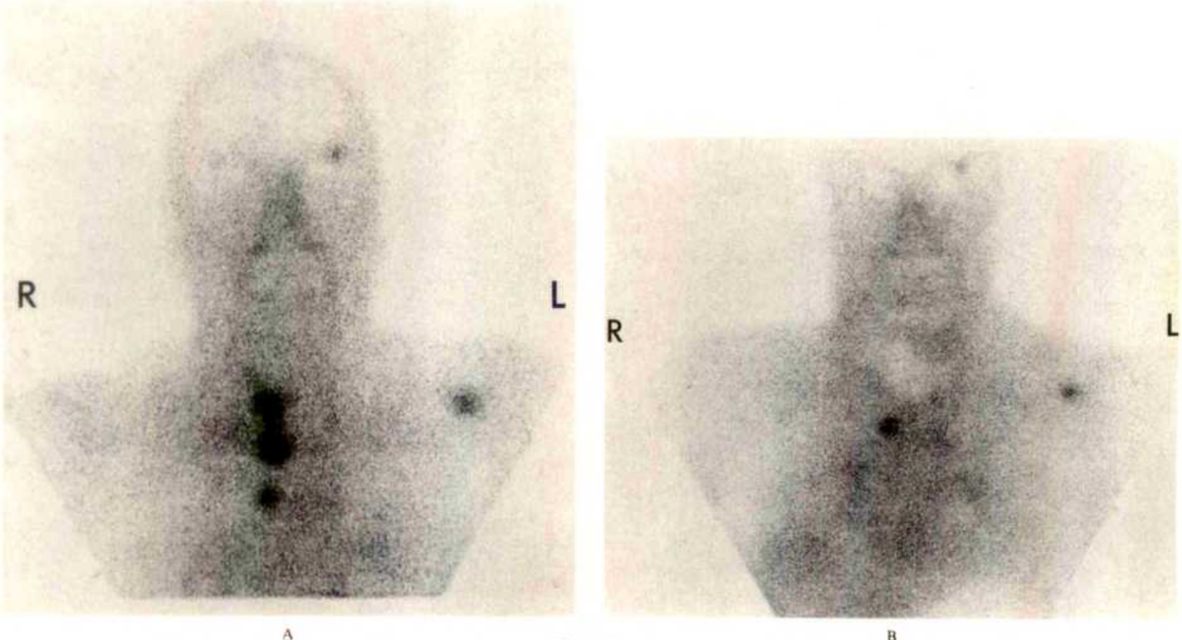


FIG. 1.

(A) Anterior view of head and neck with $^{99}Tc^{m}$(V)DMSA showing uptake in right cervical, thoracic nodes and left clavicle. Uptake is also seen in the region of the left lacrimal gland. (B) Anterior view of head and neck in same patient. Tumour in cervical nodes removed but tumour involving carotid sheath inoperable. Persistent accumulation of $^{99}Tc^{m}$(V)DMSA at this site.

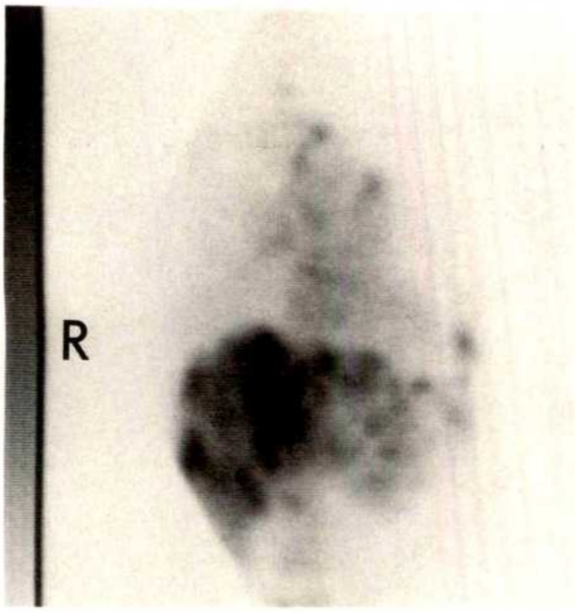


FIG. 2.

Anterior view of thorax and upper abdomen with ^{99}Tc^m(V)DMSA uptake in hepatic, vertebral and costal metastases.

with subsequent fall in calcitonin levels, but who developed sudden unexplained diarrhoea. Calcitonin levels were analysed, and while results were awaited, a ^{99}Tc^m(V)DMSA scan was performed, which proved negative. Calcitonin levels were eventually found to be normal, and the diarrhoea resolved spontaneously. The scan was therefore judged a true negative scan. The second patient with a negative ^{99}Tc^m(V)DMSA scan had persistently elevated calcitonin levels following the removal of a primary tumour, but no recurrent tumour demonstrated by any imaging modality, with a normal chest radiograph, ^{99}Tc^m MDP bone scan, ^{99}Tc^m colloid liver scan and CT scan. At present the scan has to be judged false negative. The patient will be followed with ^{99}Tc^m(V)DMSA and other imaging techniques.

DISCUSSION

The follow-up of patients with MCT following the removal of the primary tumour has been limited to estimation of plasma calcitonin levels and non-specific imaging techniques. Ohta et al (1984b) demonstrated ^{99}Tc^m(V)DMSA to be a tumour-seeking agent with high selective uptake in patients with MCT, although at present its mode of uptake is unclear. In this study, we have confirmed its uptake in sites of recurrent MCT, and demonstrated its role in management as the imaging technique of choice in the group of MCT patients with biochemical evidence of recurrence. ^{99}Tc^m(V)DMSA is a cheap, readily available radiopharmaceutical, with a radiation dose similar to that from conventional ^{99}Tc^m MDP bone scanning. High image quality is achieved with ^{99}Tc^m labelling, which gives this agent advantages over the other imaging agents currently being assessed in MCT, namely thallium-201 chloride (Parthasarathy et al, 1980) and gallium-67 citrate (Senga et al, 1982), both of which have poorer imaging characteristics. The 2 h imaging time is also more convenient than the 3–4 h imaging time for conventional ^{99}Tc^m MDP bone scanning.

We recommend that all patients with MCT having post-thyroidectomy elevations of calcitonin should have ^{99}Tc^m(V)DMSA imaging performed. Patients with uptake in the neck alone, indicating local recurrence, may then be referred for further surgery, with ^{99}Tc^m(V)DMSA imaging post-operatively to ensure complete clearance. In patients with local and distant metastases on imaging, a less aggressive approach is indicated in view of the indolent nature of the tumour in many patients. However, regular ^{99}Tc^m(V)DMSA imaging in this group, combined with sequential estimations of calcitonin levels, will indicate the aggressive nature or otherwise of the disease in any individual. In those patients whose calcitonin levels become elevated or remain elevated after a thyroidectomy, with no clinical manifestations of disease, in whom ^{99}Tc^m(V)DMSA imaging is negative and in whom there is presumed to be only microscopic disease, repeat evaluations of calcitonin level and ^{99}Tc^m(V)DMSA scans should be performed on a 6-monthly to annual basis, in order to detect macroscopic disease as it develops.

This study has explored the use of ^{99}Tc^m(V)DMSA in the assessment of local and distant recurrence in patients with MCT, with its ability to detect both bone and soft-tissue metastases. We have also demonstrated its role in the post-surgical follow-up of these patients with an accurate identification of residual tissue. We conclude that the convenience of this radiopharmaceutical and high image quality make it an invaluable adjunct to the currently accepted biochemical method of follow-up in patients with MCT.

REFERENCES

KEISER, H. R., BEAVEN, M. A., DOPPMAN, J., WELLS, S. & BUJA, L. M., 1975. Sipple's syndrome: medullary thyroid carcinoma, phaeochromocytoma and parathyroid disease. *Annals of Internal Medicine*, *78*, 561–581.

OHTA, H., ENDO, K., FUJITA, T., NAKASHIMA, T., SAKAHARA, H., TORIZUKA, K., SHIMIZU, Y., ISHII, Y., MAKIMOTO, K., HATA, N., HORIUCHI, K., YOKOYAMA, A. & ISHII, M., 1984a. Imaging of soft tissue tumours with Tc(V)-99m dimercapto-succinic acid. A new tumour seeking agent. *Clinical Nuclear Medicine*, *9*, 568–573.

OHTA, H., YAMAMOTO, K., ENDO, K., MORI, T., HAMANAKA, D., SHIMAZU, A., IKEKUBO, K., MAKIMOTO, K., IIDA, Y., KNOISHI, J., MORITA, R., HATA, N., HORIUCHI, K., YOKOYAMA, A., TORIZUKA, K. & KUMA, K., 1984b. A new imaging agent for medullary carcinoma of the thyroid. *Journal of Nuclear Medicine*, *25*, 323–325.

Parthasarathy, K., Shimaoka, K., Bakshi, S. & Razack, M., 1980. Radiotracer uptake in medullary carcinoma of the thyroid. *Clinical Nuclear Medicine*, *5*, 45–48.

Sampson, C. S., 1987. Preparation of 99Tc-m(V)DMSA. *Nuclear Medicine Communications*, *8*, 184–185.

Senga, O., Miyakawa, M., Shirota H., Makiuchi, M., Yano, K., Miyazawa, M. & Takizawa, M., 1982. Comparison of Tl-201 chloride and Ga-67 citrate scintigraphy in the diagnosis of thyroid tumour: concise communication. *Journal of Nuclear Medicine*, *23*, 225–228.

Yokoyama, A., Hata, N., Saji, H., Horiuchi, K., Tanaka, H., Morita, R. & Torizuka, K., 1981. Chemically designed ^{99}Tc^{m} radiopharmaceuticals for tumour diagnosis: ^{99}Tc^{m} DMSA. *Journal of Nuclear Medicine*, *22*, 69.

1987, *The British Journal of Radiology*, *60*, 1093–1097

November 1987

Intracavitary irradiation of endometrial cancer of large uteri using a two-phase afterloading technique

By Antti Kauppila, M.D., Pirkko Sipilä, M.D. and Antero Koivula, Ph.D.

Departments of Obstetrics and Gynaecology, and Radiotherapy, University of Oulu, Finland

(*Received March 1987 and in revised form May 1987*)

Abstract

A specific intracavitary two-phase technique was developed for irradiation of endometrial cancer located in uteri with a large uterine cavity. In this technique an insertion catheter (external diameter 9 mm) was used for the introduction and precise location of the treatment catheter (external diameter 6.4 mm). During the first phase of the therapy, one lateral half of the uterine body was irradiated. Thereafter the positions of the catheters were changed by 180 degrees, followed by irradiation of the other lateral half of the uterine body. Using a wax phantom and extirpated uteri as models, we observed that the dose distributions followed the uterine shape and the calculated doses in the radiographs. Clinical observations from 34 patients treated so far, and followed-up for periods of 3 months to 6 years, prove that this method yields similar results to those observed in previous studies employing the Heyman packing method or afterloading techniques with a one-source tandem in the intracavitary irradiation of endometrial cancer.

The afterloading technique has been beneficially used in intracavitary irradiation of cervical cancer (Joslin et al, 1972; Kauppila & Kiviniitty, 1980; Snelling et al, 1980; Taina, 1981) and in post-operative treatment of the vaginal cuff in endometrial cancer (Joslin et al, 1977; Snelling et al, 1980). We have shown previously that in pre-operative irradiation of endometrial cancer, the Cathetron afterloading technique with a one-source tandem is comparable to the Heyman packing method with respect to the clinical results and complications (Riippa et al, 1985). The use of a one-source tandem is, however, not optimal for cases in which the uterine cavity is large, *i.e.* the uterine length is greater than 9 cm. In such cases, irradiation of the uterine walls is uneven. To avoid this drawback we have developed a two-phase technique. In this paper we describe the methodological details and early clinical results obtained in the treatment of 34 patients with endometrial cancer, using this technique.

Instruments

A special insertion catheter for the introduction and correct intrauterine placement of the treatment catheters (conventional Cathetron catheters, diameter 6.4 mm) was developed (Fig. 1). The insertion catheter (diameter 9 mm) has a closed, compact 3 cm-long tip (intrauterine part) connected to the 5 cm-long hollow middle part of the catheter (endocervical part), with a caudal collar-like end (against the ectocervix). The middle part of the catheter is bent at an angle of 15–20°. A thin iron tube (vaginal part) for handling the instrument is connected to the lateral part of the collar-like caudal extension of the middle part of the instrument. In the concave side of the upper part of the hollow middle section of the catheter there is a 3 cm-long oval opening for penetration of the treatment catheter.

The radioactive material used was cobalt 60. The active length of the sources in our unit varies from 2 cm to 7.5 cm.

Measurements *In Vitro*

The distribution of the radiation in the two-source Cathetron technique was measured by various techniques. Thermoluminescence dosimetry with lithium fluoride (LiF) rods was used in the dose distribution measurements done in both the wax phantom (Fig. 2) and on the external surface of the extirpated uterus (Fig. 3). All the measured doses agreed well with the corresponding calculated ones.

Treatment Principles of the Two-phase Method

After cervical dilatation and introduction of the insertion catheter, the upper, compact part of the catheter was along the lateral uterine wall. The treatment catheter was then introduced through the cervical part of the insertion catheter. The intrauterine part of the treatment catheter was along the lateral uterine wall opposite to the position of the insertion catheter (Fig. 4). One uterine lateral half was then irradiated. The treatment catheter was then drawn out and the insertion catheter was turned within the uterine cavity by 180°, followed by replacement of the treatment catheter. The intrauterine parts of the catheters were now along the lateral uterine walls opposite to those of their first positions. The other lateral half of the uterus was then irradiated, followed by removal of the instruments. Pelvic radiography was used for control and documentation of the positions of the catheters during both treatment phases. Dose distribution was ascertained by means of radiographs (Fig. 4).

The use of radioactive sources with active lengths of

Address for correspondence: Antti Kauppila, Department of Obstetrics and Gynaecology, University of Oulu, SF-90220 Oulu, Finland.

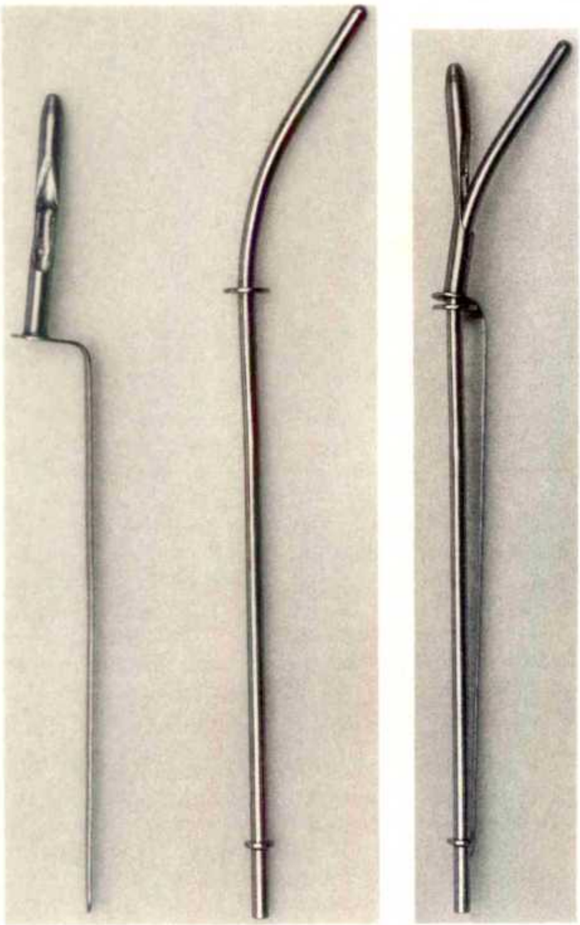


FIG. 1.

Insertion and treatment catheters separately (A) and together in the treatment position (B).

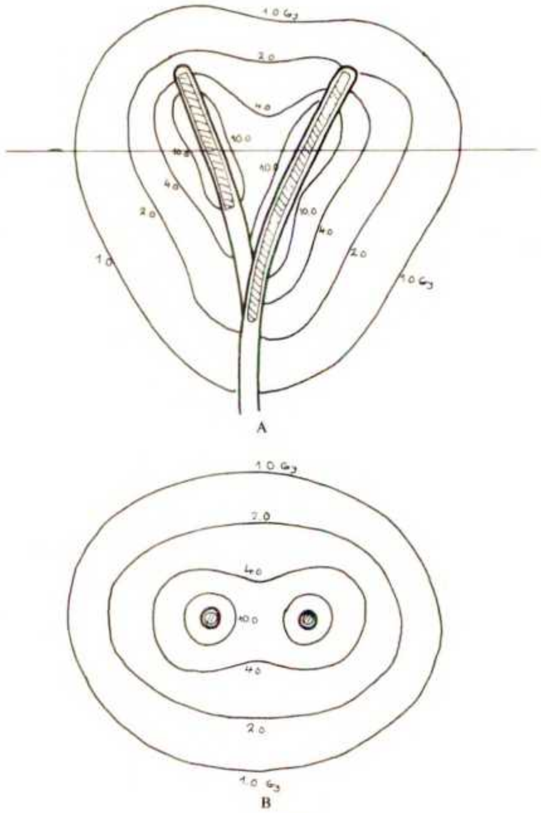


FIG. 2.

Dose distributions measured with lithium fluoride rods in a wax-model during two-phase treatment using a 7.5 cm-long radioactive source (A) in the first phase and a 4 cm-long radioactive source (B) during the second phase of the irradiation. Below: cross-section at the level indicated by line.

7.5 cm and 4 cm successively was practical for cases with uterine lengths of 10–11 cm (Figs 2, 3 and 4). With a 7.5 cm-long source, one lateral half of the uterine body and the uterine cervix were irradiated, and during the second phase the opposite lateral half of the uterine body was irradiated with a 4 cm-long source. If the uterine length was 12 cm or longer the irradiation was given in three doses. The cervical part of the uterus was irradiated with a source of an active length of 2–4 cm, and both lateral halves of the uterine body with a source of an active length varying from 4.5 cm to 7.5 cm.

PATIENTS

From 1980 to 1986, 34 patients with endometrial cancer have been treated with two-phase intracavitary irradiation (Table I). The uterine length in these cases varied from 10 cm to 16 cm. In 27 cases, intracavitary irradiation was given before operation (total abdominal hysterectomy and bilateral salpingo-oophorectomy; TAH + BSO), followed by pelvic irradiation in 10 cases (anaplastic malignancy, deep myometrial infiltration or advanced disease). Two patients were treated with intracavitary irradiation alone and five patients with intracavitary irradiation together with external pelvic beam therapy (Betatron, 45 MeV). In 28 women the disease was confined to the uterine body, whereas six women had more advanced disease. The clinical follow-up of the patients varied from 1 to 6 years in 32 cases, but it was only 3 months in two cases. Pre-operative irradiation with the two-phase technique was given in four sessions over 12 days. The dose of irradiation was 8 Gy to a 1 cm depth of myometrium in each session, to a total dose of 32 Gy. In combination radiotherapy, five treatments with two-phase intracavitary irradiation (at the same dose as in pre-operative irradiation) were given in association with pelvic radiotherapy at a total dose of 40–45 Gy (3.5 Gy three times weekly). There was a break of 3 weeks in the middle of the whole treatment period, which lasted approximately 8 weeks

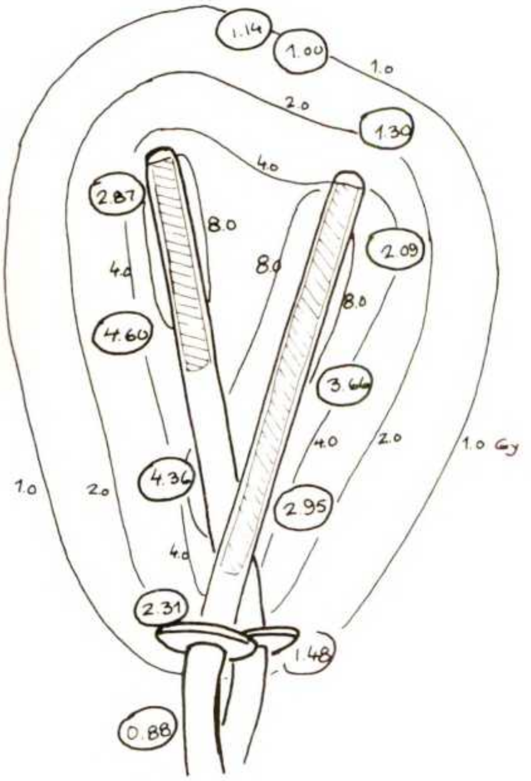


FIG. 3.

Results of dose measurements with lithium fluoride rods on the surface of an extirpated uterus (circled figures) in comparison with the calculated dose distributions (solid lines) after two-phase treatment using a 4 cm-long radioactive source during the first phase of irradiation and a 7.5 cm-long radioactive source during the second phase of irradiation.

TABLE I

THE NUMBER OF PATIENTS IN DIFFERENT TREATMENT CATEGORIES IN CLINICAL STAGES I, II AND III

	Pre-operative irradiation followed by		Irradiation alone	
	Surgery and pelvic irradiation	Surgery alone	Intra-cavitary irradiation alone	Intra-cavitary and external irradiation
Stage I (28)	7	17	1	3
Stage II (4)	1	0	1	2
Stage III (2)	2	0	0	0
Totals	10	17	2	5

in total. The total dose to a 1 cm depth of myometrium was thus 80–85 Gy. Two patients in poor general condition received intracavitary irradiation alone, six times 8 Gy to a depth of 1 cm of the myometrium (48 Gy in total), over 7 weeks, with a break of 3 weeks in the middle of the whole treatment period.

TREATMENT RESULTS

In the whole group of 32 patients with clinical Stage I or II disease, four patients contracted recurrent disease (Table II). Two recurrences developed in the group of 25 patients with intracavitary irradiation followed by TAH + BSO and the other two in the group of five patients treated with intracavitary and external radiotherapy.

Evaluation of the results of histopathological examination of the uterus was possible in 21 cases.

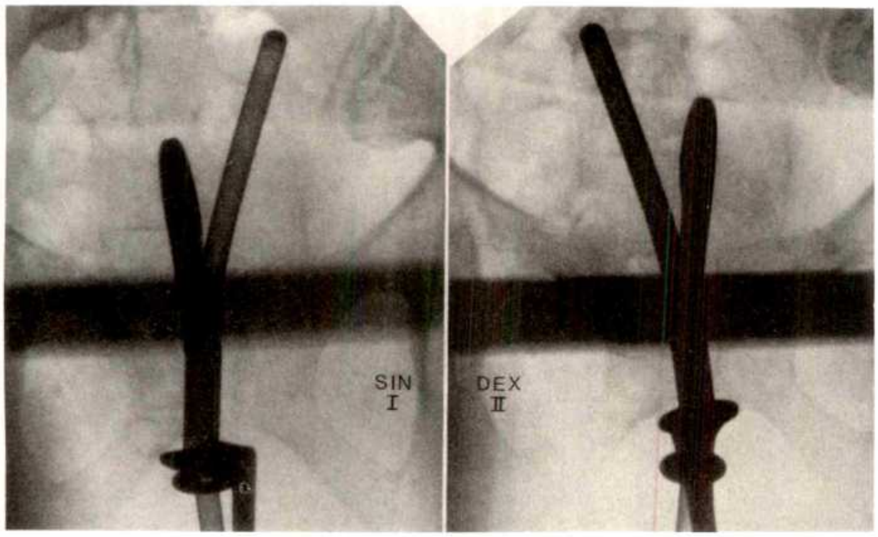


FIG. 4.

Radiographs taken after the insertion of catheters for the first phase of irradiation (left half of the uterine body; sin I) and for the second phase of irradiation (right half of the uterine body; dex II).

TABLE II

TREATMENT RESULTS

Clinical stage and therapy	No. of patients	Pelvic recurrence	Distant recurrence	Alive		Died of	
				disease-free	with recurrent disease	endometrial cancer	intercurrent disease
I+II	32	1	3	22	2	2	6
Radiotherapy+surgery	25	1	1*	20	1	1	3
Intracavitary irradiation	2	—	—	2	—	—	—
Combined radiotherapy	5	—	2†	—	1	1	3
III							
Radiotherapy+surgery	2	1	1‡	—	1	1	—

*Umbilical recurrence.
†Lung recurrences.
‡Liver recurrence.

Carcinomatous tissue was present in 16 cases, with superficial invasion (less than one third of the myometrium) in eight cases, moderate invasion (from one third to one half of the myometrium) in five cases and deep invasion in three cases (more than half of the myometrium), while five specimens were apparently free of malignant tissue.

One of the two patients with clinical Stage III disease died of recurrent disease in the liver 34 months after the treatment, while the other one is alive at 54 months, with pelvic recurrence (Table II).

One patient with Stage III disease suffered from rectal bleeding about 12 months after the treatment. Radiation-induced dysuria was observed in three women and vaginal stricture in two women during the follow-up period.

DISCUSSION

Intracavitary irradiation is an essential part of the radiotherapy of patients with inoperable endometrial cancer, either alone or together with external radiotherapy. In addition, some centres of gynaecological oncology advocate the use of pre-operative intracavitary irradiation, although this treatment method and external post-operative radiotherapy yield similar clinical results (Salazar et al, 1978). Intracavitary irradiation is most commonly accomplished by the Heyman packing method, in which the radioactive material is inserted manually (Heyman, 1929; Heyman et al, 1941). We have previously shown that with a one-source tandem technique, the afterloading unit Cathetron is useful for the intracavitary irradiation of endometrial cancer in small to moderate-sized uteri (Riippa et al, 1985). With the present data we widen the spectrum of patients suitable for intracavitary irradiation using a remote afterloading technique. We demonstrate here that using a specific insertion instrument for the precise placement of the intrauterine radioactive sources, and applying a two-phase treatment strategy, endometrial cancer can be effectively and homogeneously irradiated even within a large uterus.

The advantages of the new method over the Heyman packing method are the same as those previously presented when manual and afterloading intracavitary irradiation methods have been compared (Fleishman et al, 1983); the afterloading method is rapid, it causes no radiation hazards to the staff or visitors, the irradiated area can be determined accurately and the position of the sources does not change during the short-term treatment, and so on. Our measurements *in vitro* confirmed that in the two-phase treatment with 2 to 7.5 cm-long radioactive sources, the isodose curves closely resembled the shape of the uterus. The present clinical data on 34 patients treated with the new method also demonstrated that the rates of recurrent disease or complications were comparable to those seen in previous studies employing one-source tandem or Heyman packing methods (Kauppila et al, 1982; Riippa et al, 1985). The same is also true for radiation-induced complications (Riippa et al, 1985).

Treatment with the two-phase technique is more laborious and time-consuming than Cathetron treatment of cervical cancer or endometrial cancer with a one-source tandem. It is worth emphasising that this method cannot be used in cases with extensive elongation or marked rigidity of the uterine cervix, or in cases with a significantly deformed uterine cavity because of uterine fibroids.

In conclusion, our findings demonstrate that methodological obstacles can nearly always be overridden in replacing the manual Heyman packing method with an afterloading technique in the intracavitary radiotherapy of endometrial cancer.

REFERENCES

FLEISHMAN, A. B., NOTLEY, H. M. & WILKINSON, J. M., 1983. Cost benefit analysis of radiological protection: a case study of remote after-loading in gynaecological radiotherapy. *British Journal of Radiology*, *56*, 737–744.

HEYMAN, J., 1929. The technique in the treatment of cancer uteri at Radiumhemmet. *Acta Radiologica*, *10*, 49–64.

HEYMAN, J., REUTERWALL, O. & BRENNER, S., 1941. The Radiumhemmet experience and radiotherapy of corpus cancer of the uterus; classification, method of treatment, and results. *Acta Radiologica*, *22*, 11–98.

JOSLIN, C. A. F., SMITH, C. W. & MALLIK, A., 1972. The treatment of cervix cancer using high activity ^{60}Co sources. *British Journal of Radiology*, *45*, 257–270.

JOSLIN, C. A., VAISHAMPAYAN, G. V. & MALLIK, A., 1977. The treatment of early cancer of the corpus uteri. *British Journal of Radiology*, *50*, 38–45.

KAUPPILA, A., GRÖNROOS, M. & NIEMINEN, U., 1982. Clinical outcome in endometrial cancer. *Obstetrics and Gynecology*, *60*, 473–480.

KAUPPILA, A. & KIVINIITTY, K., 1980. High dose-rate intracavitary irradiation in the treatment of cervical and endometrial carcinomas: preliminary observations. In *High Dose-rate Afterloading in the Treatment of the Cancer of the Uterus*. BIR Special Report 17. Ed. by T. D. Bates & R. J. Berry. (British Institute of Radiology, London), pp. 59–64.

RIIPPA, P., KIVINEN, S. & KAUPPILA, A., 1985. Comparison of Heyman packing and Cathetron afterloading methods in the treatment of endometrial cancer. *British Journal of Radiology*, *58*, 437–441.

SALAZAR, O. M., FELDSTEN, M. L., DEPAPP, E. W., BONFIGLIO, T. A., KELLER, B., RUBIN, P. & RUDOLPH, J. H., 1978. The proper management of endometrial cancer. *Cancer*, *41*, 230–240.

SNELLING, M. D., LAMBERT, H. E. & YARNOLD, J., 1980. Clinical results and complications following treatment of carcinoma of cervix and endometrium using the Cathetron at the Middlesex Hospital. In *High Dose-rate Afterloading in the Treatment of Cancer of the Uterus*. BIR Special Report 17. Ed. by T. D. Bates & R. J. Berry. (British Institute of Radiology, London), pp. 32–37.

TAINA, E., 1981. A comparison of clinical results following high dose-rate intracavitary afterloading irradiation with ^{60}Co (Cathetron) and conventional radium therapy for Stage I–II endometrial carcinoma. *Acta Obstetrica et Gynaecologica Scandinavica*, *103*, 59–66.

Book reviews

Advances in Immunity and Cancer Therapy. Vol. 2. Ed. by P. K. Ray, pp. x+301, 1986 (Springer Verlag, New York), DM148.
ISBN 0-387-96258-1 (New York)
3-540-96258-1 (Berlin)

This is a book in physical form only. It contains six independent reviews, each with its own bibliography and list of acronyms. There is a 19-line preface but this is uninformative and no attempt is made to link the various topics. Illustrations consist of six line drawings and one halftone figure; this paucity is not necessarily a disadvantage but does not correspond with the high price (DM148) of the book.

Chapter 1, by D. Noor and J. S. Duke-Cohan, is the first of two articles on suppressor cells and malignancy, the second of which is due to appear in a later volume. It develops further ideas discussed in a review article by one of the authors that appeared in *Advances in Cancer Research* in 1979 concerning the interrelationship between a tumour and cells involved in regulating the immune response, with special reference to immunosuppressive effects mediated by macrophages and T-cells. The authors discuss the possibility of augmenting the resistance to a tumour by eliminating suppressor T-cells by means of cytotoxic drugs, splenectomy, thymectomy and low dose irradiation, but sound a warning that it may be difficult to know when enhanced tumour growth is really due to suppressor cell activity. While it is salutary to be reminded that suppressor cells may influence tumour behaviour, much more work is needed before the therapeutic implications of this will be clearly delineated.

Chapter 2, by Sudhir Gupta, is concerned with abnormal function of immunoregulatory T-cells in human neoplasms. It is packed with information, but the reader is left to draw for himself such general conclusions as he can.

Chapter 3, by P. K. Ray and Sandip Saha, compares tumour growth and fetal development. This is an interesting and well written review, but adds little to what has been said many times before.

Chapter 4, by F. A. Salinas and K. H. Wee, focuses on circulating immune complexes in cancer patients, and the prognostic significance of the composition and concentration of such complexes in patients with malignant melanoma. Readers not familiar with the work of Salinas and his colleagues will find this a useful introduction and guide to the literature.

Chapter 5, by J. P. Dutcher, is a practical guide to the transfusion of blood platelets and granulocytes in patients with bone marrow hypoplasia, and discusses the techniques used, as well as the indications for, and dangers of, these procedures.

Chapter 6, by K. Fujiwara and T. Kitagawa, discusses the production in animals of antibodies to a wide range of anti-cancer drugs, and the use of such antibodies in monitoring drug levels in patients' sera by immunoassay.

Different chapters will interest different categories of reader. The first four chapters are of value mainly as guides to the literature rather than as inspirational reading. The last two will be of special interest to practising oncologists; in addition, the last chapter provides useful information for those who wish to prepare anti-drug antibodies for themselves.

The book contains 1463 references, but less than 100 of these were published later than 1983. Although it could be updated in places, it is a useful book to have in a hospital or university library, but many individuals may feel that they could spend DM148 to better advantage.

M. WOODRUFF

Treatment Planning in the Radiation Therapy of Cancer. Ed. by J. M. Vaeth and J. Meyer, pp. ix+338, 1987 (S. Karger AG, Basel), £147.80.
ISBN 3-8055-4377-8

This book has been published as the twenty-first volume in a series entitled *Frontiers in Radiation Therapy and Oncology*. It contains the proceedings of the twenty-first Annual San Francisco Cancer Symposium which was held at the end of February and beginning of March 1986, and consists of 21 papers plus three pages of verbatim discussion. Somewhat surprisingly, the discussion section appears in the middle of the book and refers only to the first ten chapters, perhaps because the programme on the first day ran ahead of schedule! For review purposes however, the discussion section conveniently divides the book into two halves, pre-discussion papers being generally of a more technical nature whereas the later ones have a more clinical bias.

The quality of the papers in the first half is variable, and sadly in two or three cases the editors must be criticised for accepting inadequate contributions. The first chapter on fractionation and daily dose, for example, is extremely short and without references. The anecdotal style is not without a certain charm, but it will be a disappointment to those looking for scientific content. A later chapter on multiview three-dimensional treatment planning is totally devoid of photographs and diagrams to illustrate the text, and if ever a subject cried out for illustration this would be it! By contrast, the chapter on state-of-the-art high energy photon treatment planning is well illustrated and worth reading, and is one of the few that totally justify inclusion in a volume claiming to reflect work at the frontiers of the speciality. It is perhaps not too surprising that it is one of the illustrations from this chapter that has been chosen to adorn the front cover. Other interesting, but sometimes controversial ideas are discussed in further chapters on image correlation for treatment planning, the use of dose volume histograms, and evaluation of computer controlled radiotherapy. In the final four chapters in this half there is a shift towards more specialised techniques with papers on total body irradiation, particle beams, brachytherapy, and hyperthermia.

The eleven papers in the second half of the book are devoted to eleven areas of clinical interest. In each, the authors discuss various aspects of radiotherapy management of the cancers concerned, often referring to their own practice, and with varying degrees of emphasis on what is generally regarded as treatment planning. It is difficult to know who will benefit from reading these papers, since elsewhere around the world other radiotherapists will claim that their own well-established techniques are just as good, if not better, than those described. Presentations in the second half are of a more uniform standard with all of the authors making a commendable effort.

The book must be regarded as highly priced, and ridiculously so, despite the top quality paper and smart cover; these, after all, are not high on the list of criteria by which a book is judged. The contents, I fear, may prove to be a disappointment to those expecting to extend considerably their knowledge about activities at the frontiers of the speciality, and anyone who actually purchases the book at the publishers asking price may even feel a little cheated!

J. M. WILKINSON

1987, *The British Journal of Radiology*, *60*, 1099–1108 NOVEMBER 1987

The influence of field size on the late tolerance of the rat spinal cord to single doses of X rays

By J. W. Hopewell, A. D. Morris & *A. Dixon-Brown

CRC Normal Tissue Radiobiology Research Group, Research Institute (University of Oxford), Churchill Hospital, Oxford and *Department of Radiation Physics, Churchill Hospital, Oxford

(*Received April 1987 and in revised form June 1987*)

ABSTRACT

Varying lengths of the cervical spinal cord of rats were irradiated with single doses of X rays. Dose-related changes in the latency for the development of paralysis, or for the presence of histological lesions in the spinal cord, indicated a dependency on the length of spine irradiated. The dose associated with a specified latency increased as the field size was reduced from 16 mm to 4 mm. A more precise indication of the importance of field size came from a determination of the ED_{50} values for rats developing paralysis in <30 weeks of irradiation or from those that showed neurological signs, or histological evidence, of irradiation damage, occurring after latent periods of >30 weeks. These end-points were primarily related to white-matter necrosis and gross vascular damage respectively. For paralysis in >30 weeks the ED_{50} increased markedly from 21.5 ± 0.3 Gy for a 16 mm field to 50.98 ± 2.28 Gy when a 4 mm length of cord was irradiated. For vascular lesions only a small change in ED_{50} value was found, from 20.0 ± 0.5 Gy to 25.58 ± 2.78 Gy for 16 mm and 4 mm fields respectively. At $\leqslant ED_{25}$ no evidence for a field-size effect was seen for this late lesion. These results were examined in the light of some old and some more recently analysed clinical data for radiation myelopathy. It is hoped that this will initiate other investigations in this important area of radiotherapy practice.

In radiotherapy it has been recognised for a considerable time that the response of normal tissues to radiation may be influenced by the volume of tissue irradiated. Thus, clinically it is usual to reduce the total dose if field sizes are increased. However, it is important to distinguish between an increase in the severity of the effect produced by a unit of dose with increasing volume and an increase in morbidity produced by the same level of effect (for the same unit of dose) in a larger tissue volume.

For acute skin reactions in man, moist desquamation was usually considered to be acceptable in small fields. However, this level of effect produced unacceptable morbidity in larger fields and hence doses were reduced. These subjective assessments were taken into account in the skin tolerance doses proposed by Ellis (1942) and others. This has been discussed extensively elsewhere (Hopewell & Young, 1982). It is perhaps regrettable to the future understanding of volume effects that subsequent authors (von Essen, 1969; Schultheiss, 1983) have used data of the type presented by Ellis (1942) to represent increasing effects, per unit of dose, with increasing field size.

In the treatment of head and neck cancer the risk of developing myelopathy, as a consequence of late radiation injury to the spinal cord, represents a more objective assessment of the tolerance to therapy. This risk does not change as a function of the length of the spine irradiated. Present clinical guidelines as to the variation in cord tolerance with field size are largely based on the early findings of Boden (1948). In this classical paper on radiation myelitis of the cervical cord in man, it was suggested that relatively long lengths of cord ($\geqslant 10$ cm) should not receive more than 35 Gy in 17 days. Smaller fields on the other hand ($\leqslant 8$ cm) would appear to tolerate a larger dose; however, a dose of 50 Gy given over the same time period, did lead to permanent damage in some patients. Since that date numerous authors have alluded to a field-size effect for spinal cord (Pallis et al, 1961; Philips & Buschke, 1969; Holdorff, 1980) although few or no additional data were presented. The only other clinical data on this topic were provided by Abbatucci et al (1978). From an analysis of patients developing myelopathy they demonstrated that the upper limit of tolerance for a $\geqslant 5$ cm length of the cervical spine was 50 Gy (25 fractions/35 days), paralysis being a consistent finding in those patients receiving $\geqslant 60$ Gy. No myelopathy was seen in patients irradiated to $\leqslant 5$ cm of cord, even after 60 Gy.

Thus, while the clinical data provides some evidence for a field-size effect in the spinal cord, no precise relationship has been established. Such a relationship might be best obtained from animal studies, which are also likely to provide a better understanding of the underlying mechanisms. However, at present very few animal studies have been carried out. Following the irradiation of 1–16 mm lengths of cervical cord in rats, the clinical signs, latent period and histological changes observed were dependent on dose and field size (Hopewell & Wright, 1975). An increase in the ED_{50} for myelopathy was found in mice when a 6 mm segment compared with a 12 mm segment of cord was irradiated (Goffinet et al, 1976) and in the rabbit brain, evidence for a field-size effect was obtained when 1–12 mm-wide "slit" fields were irradiated (Berg & Lindgren, 1963).

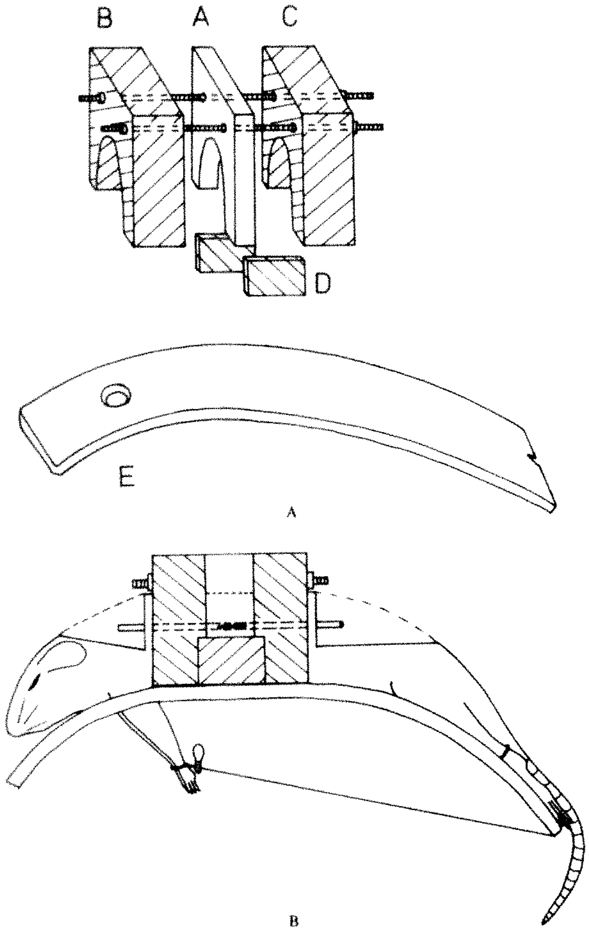


Fig. 1.

Diagrammatic representation of the jig used to irradiate 4–16 mm lengths of spinal cord in the rat. Upper panel (A) the lead shield (E) supported the body of the rat, while the irradiation port was formed by the two lead blocks (B) and (C) separated by an appropriate thickness of Perspex (A). Sensitive structures within the irradiation port were shielded with lead (D). Lower panel (B): dosimetry was carried out using a frozen rat with TLDs placed within the spinal canal.

In the rat, a model has been developed which has allowed a precise dose–effect relationship to be established for myelopathy following the irradiation of the cervical spine (van der Kogel, 1979). Using this model, two distinct pathologies have been recognised; selective white matter necrosis resulting in paralysis in <30 weeks and vascular lesions in grey and white matter leading to paralysis after a varying latent interval of 8–18 months (van der Kogel, 1983). Of these two lesions, the vascular-mediated damage which occurs after lower doses, is perhaps of greater clinical relevance. However, a recent review of radiation myelopathy in patients has also shown the latent period to be bimodally distributed (Schultheiss et al, 1984).

In the present investigation the model developed by van der Kogel (1979) has been used to assess the influence of the length of cervical spinal cord irradiated on the tissue "tolerance" for both the white matter and vascular-related lesions. In addition, the relationship between latent period and dose for the development of myelopathy was assessed since previous studies in the rat (White & Hornsey, 1978) and mouse (Geraci et al, 1978) have successfully used this end-point to examine the effects of dose fractionation and high linear energy transfer (LET) radiations.

Materials and Methods

Young adult (12–14-week-old) female rats of the Sprague Dawley strain were used. Three different lengths of the cervical spine, 4, 8 or 16 mm, were locally irradiated with single doses of 250 kV X rays while the rats were under chloral hydrate anaesthesia (300 mg/kg). Doses of 18.0–24.0 Gy, 20.4–40.0 Gy and 25.3–70.0 Gy were given to 4, 8 and 16 mm lengths of spinal cord respectively. Groups of six rats were irradiated at each dose level for each field size.

During the course of irradiation the animals were fixed to a special jig (Fig. 1A). This was based on a modification of a technique used by Carsten and Zeman (1966). This consisted of a 5 cm-wide, curved shield in 6 mm lead (E) which had a hole at one end through which the forelimbs could be restrained (Fig. 1B). The body of the animal was flexed over the jig and the hind limbs secured with tape. Perspex pieces (A) of width 4, 8 or 16 mm were then placed over the neck of the rat. These were shaped to provide a close but not a tight fit over the rat. These Perspex spacers, which formed the irradiation port, were sandwiched and clamped between two similarly shaped blocks of lead (B and C). The position of the port was checked fluoroscopically prior to irradiation; the large vertebral spine of vertebra T2 was used as the lower marker of the irradiation field, irrespective of the field width. Small pieces of 3 mm lead (D) were positioned to protect the oesophagus during irradiation of the spinal cord. Two rats could be irradiated at a time in this way, placed back to back close to the central axis between two parallel opposed 250 kV X-ray beams with focus-screen distances of 50 cm. The rest of the body of the animal was shielded with 3 mm of lead. The X-ray machine was operated at 15 mA with 0.5 mm Cu and 1.0 mm Al added filtration (half-value layer 1.4 mm Cu).

Dosimetry for these irradiations was carried out in a dead 12-week-old female rat which had been frozen *in situ* in the irradiation jig. Tissue was removed well outside the irradiated volume to enable the spinal cord to be drilled out. An appropriately sized polythene tube was then inserted into the spinal canal (Fig. 1B). For the measurement of dose in the 16 mm and 8 mm fields lithium fluoride (LiF) rods (6 mm × 1 mm) were placed singly within this polythene tube. For the 4 mm field size the LiF rods were placed in a separate hole at right angles to the spinal cord. The position of each rod within the irradiation field was measured by offset from the end of the polythene tube. In place of a second rat a Perspex phantom was used so that the overall field size and scatter conditions were preserved.

A batch of 24 LiF rods (Harshaw TLD 100) were used; they were calibrated against a Farmer clinical substandard dosemeter. The calibration was carried out in the centre of 6 cm of tissue-equivalent rubber. From several calibrations the average relative sensitivity of each rod was established. When rods were irradiated in the frozen rat to establish the field-size correction factors, several rods were also irradiated using the standard calibration set-up. This corrected for any drift in the thermoluminescent dosemeter (TLD) system.

Since two animals were irradiated together, back to back with a Perspex spacer between them, then effectively 90 mm-long slit-fields of varying width were used. The field-size correction factors were normalised to the 16 mm-wide field: they were found to be 0.90 for the 8 mm-wide field and 0.84 for the 4 mm-wide field. These values were in good agreement with calculated field-size correction factors of 0.88 for an 8 mm-wide field and 0.81 for a 4 mm-wide field. These calculations took into account the change in backscatter and depth dose for fields of varying equivalent square side (Dixon-Brown & Hopewell, 1988). Such calculations are of general value in radiobiological studies with animals when small fields are involved.

Following irradiation, the animals were housed in groups of six. They were examined at least three times per week to determine the presence of the first neurological signs that might lead to paralysis. Animals that developed paralysis, or those that had to be killed because of a general deterioration in their condition, were perfusion-fixed under light ether anaesthesia with a mixture of 10% formal saline with 1% acetic acid. For animals that died without prior signs, the cervical and upper thoracic spine was immersed in the same fixative. Following fixation, this region of the vertebral column was decalcified in 8% formic acid for 10 days. Transverse slices, 2 mm thick, of the irradiated spine were taken. These were dehydrated and embedded in paraffin wax. Sections were cut at 5 μm and stained with either Mayer's haematoxylin and eosin or Luxol Fast Blue PAS.

RESULTS

In the group of rats in which 16 mm of spinal cord was irradiated, only forelimb paralysis was seen, whereas both fore- and hind-limb paralysis was seen in the 8 mm and 4 mm field-size groups. The progression of neurological changes associated with forelimb paralysis was characterised by (a) slight ataxia and sporadic dragging of the feet, (b) regular dragging of the feet with curling of the toes; animals had a reduced ability to walk, and (c) forelimb paralysis. The animals had by then assumed a characteristic posture with an arched lower back. Hind-limb paralysis was also associated with (a) a tendency to drag the hind legs with the feet turned outwards. This progressed to (b) a clearly defined weakness of the hind legs, with the inability of the toes to grasp, and (c) severe paralysis with a reduced ability to move forward. Both fore- and hind-limb paralysis were usually accompanied by urinary incontinence and weight loss, which became more severe as paraplegia progressed.

The progression of paralysis from its onset was rapid after high doses, reaching severe paralysis (c) within 2 weeks. Such changes occurred within 30 weeks of irradiation and, hence, the latency for the first appearance of neurological damage (a) could be clearly defined. However, in the lower-dose groups, poorly defined weakness or ataxia of the limbs was observed for many weeks before definite paralysis developed. These changes occurred after time intervals greater than 30 weeks. In a few cases animals were killed after a gradual deterioration in their general condition, other rats died spontaneously and it was only possible to identify a neurological association from histological observations made on the irradiated spinal cord. Therefore, the latency for the first appearance of neurological damage in such animals was less well defined.

The relationship between the mean latent period, in animals developing radiation damage to the spinal cord, and dose for each of the three field sizes is shown in Fig. 2. The mean latency clearly declined with increasing dose, reaching a value of <30 weeks for doses of $\geqslant 23$ Gy, 40 Gy and $\geqslant 54.5$ Gy for fields of length 16, 8 and 4 mm respectively. A mean latency of 60 weeks was associated with a dose of ~ 20.5 Gy for a 16 mm field and ~ 24 Gy and ~ 40 Gy for 8 mm and 4 mm fields respectively.

When the animals were subdivided according to the nature of the predominant histological lesion (either white-matter necrosis or gross vascular abnormalities), which in practical terms involved latent periods of <30 weeks or >30 weeks, then differences became apparent (Fig. 3). For latencies of <30 weeks (white-matter necrosis) there was no clearly defined dose dependency for the two larger field sizes. There was a suggestion of a dose dependency when 4 mm of spinal cord was irradiated, although the number of animals involved was small. The variation in latency in all dose groups was small.

When animals survived for >30 weeks, there was a considerable variation in the latency. However, the mean latency did appear to be linearly related to the dose for the three different lengths of spinal cord irradiated, although, in the case of the smallest field size (4 mm), the mean latent period after a dose of 25.3 Gy was not significantly different from that after 47.8 Gy ($p > 0.5$).

A more precise estimate of the influence of field size was obtained from an analysis of the dose-related incidence of specific reactions. For paralysis developing

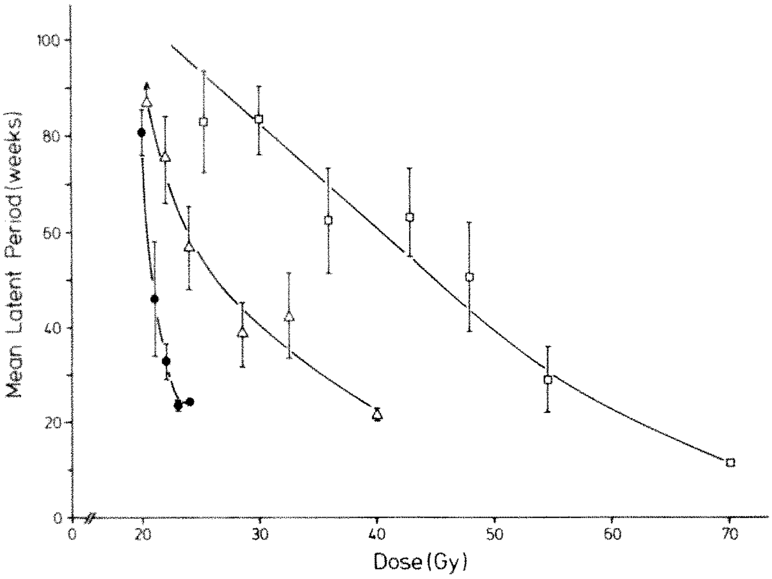


FIG. 2.

Dose-related changes in the mean latency for animals developing radiation-induced damage to the spinal cord. Single doses were given to 16 mm (●), 8 mm (△) and 4 mm (□) of the cervical spine. Error bars indicate ±SE.

within 30 weeks, a distinct relationship with field size was seen. The dose required to produce paralysis in 50% of rats (ED_{50}) increased from 21.5±0.3 Gy for a 16 mm field to 50.98±2.28 Gy for a 4 mm field (Fig. 4). For animals developing paralysis at intervals >30 weeks and/or those rats showing histological evidence for vascular damage, the field-size relationship was less clearly defined: the increase in ED_{50} from 20.0±0.5 Gy for a 16 mm field to 25.58±2.78 Gy for a 4 mm field was significant ($p < 0.05$). However, at $\leqslant ED_{25}$ no significant field-size effect was observed (Fig. 5). The difference in field-size effect relationship for these two types of reaction, which have been loosely characterised as white-matter necrosis (<30 weeks) and vascular damage (>30 weeks), are illustrated in Fig. 6. The ED_{50} values and the length of spinal cord irradiated were highly linearly correlated ($r \geqslant 0.986$) with slopes of -0.63 and -0.18 for white matter- and vascular-related damage respectively.

The histological changes seen in the spinal cord of animals after the irradiation of a 16 mm-long field were identical to those that have been described in detail by others (van der Kogel, 1980, 1983). Animals that developed paralysis within 30 weeks had white-matter

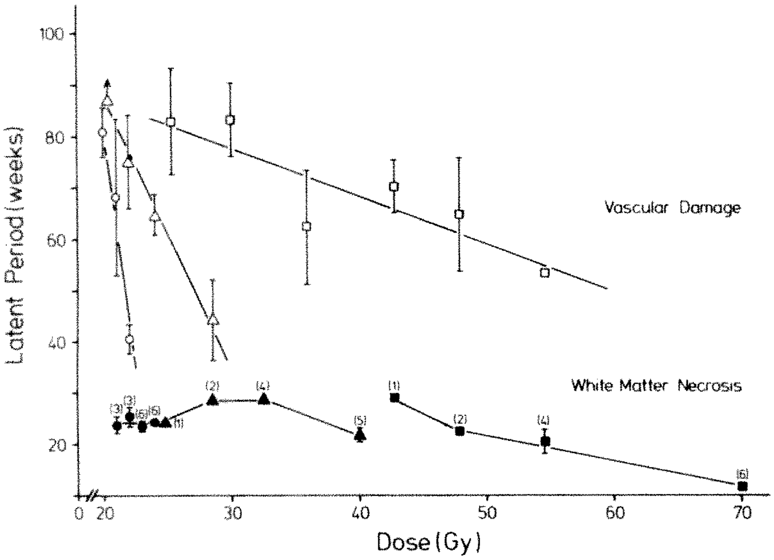


FIG. 3.

Dose-related changes in the mean latency for animals developing radiation-induced damage, separated according to the nature of the predominant histological lesion. Rats showing white-matter necrosis (solid symbols) developed paralysis with a latent period of <30 weeks. For rats that developed vascular lesions (open symbols) the latency was >30 weeks and was more variable. Irradiation was with single doses to 16 mm (○●), 8 mm (△▲) and 4 mm (□■) of the cervical spine. Six animals were irradiated in each dose group; the number of rats developing white matter necrosis is given in parenthesis. Error bars indicate ±SE.

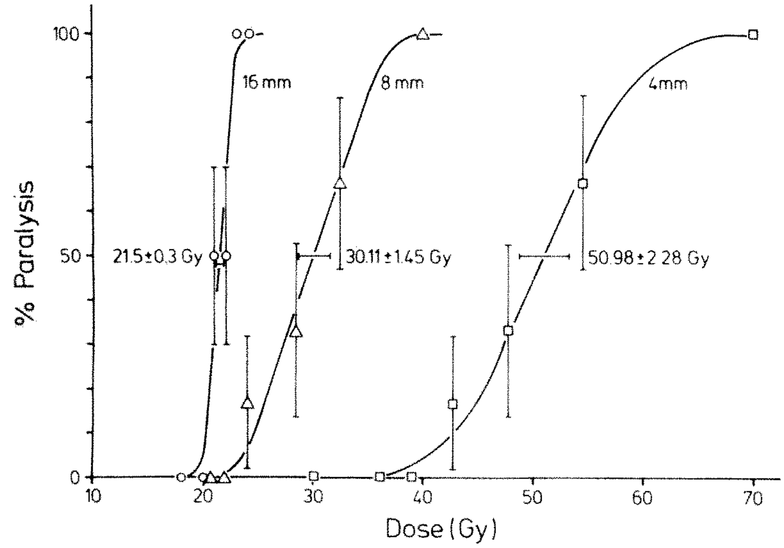


FIG. 4.

Dose-related changes in the percentage of rats developing paralysis within 30 weeks after single doses of radiation to 16 mm (○), 8 mm (△) or 4 mm (□) of the cervical spine. The ED_{50} values (±SE) are indicated.

necrosis without damage to the grey matter or nerve roots. Those developing paralysis between 37 weeks and 99 weeks after irradiation showed a varying severity of telangiectasia in grey and white matter. Two animals had large haemorrhages.

For the two smaller field sizes this demarcation, with respect to histological lesions on the basis of latency, was not so clearly defined. In animals that developed paralysis after a latent period of greater than 30 weeks, vascular lesions were seen in both the grey and white

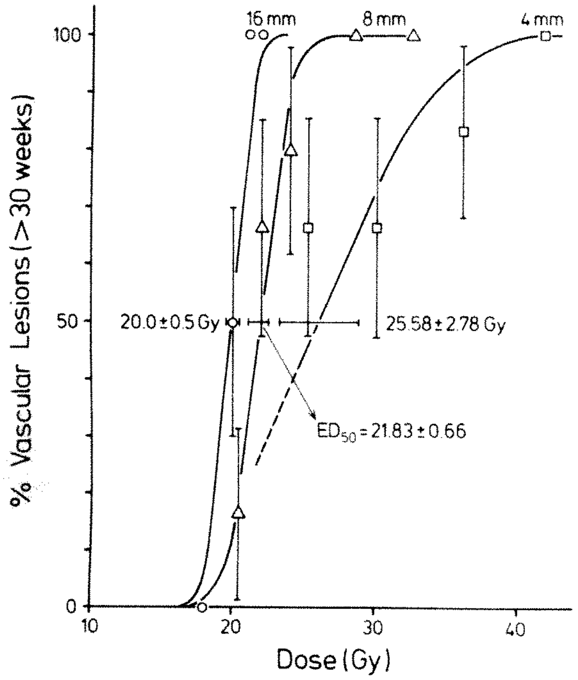


FIG. 5.

Dose-related changes in the percentage of rats developing paralysis or showing histological evidence of vascular lesions after a latent interval of >30 weeks after single doses of radiation to 16 mm (○), 8 mm (△) or 4 mm (□) of cervical spine. The ED_{50} values (±SE) are indicated.

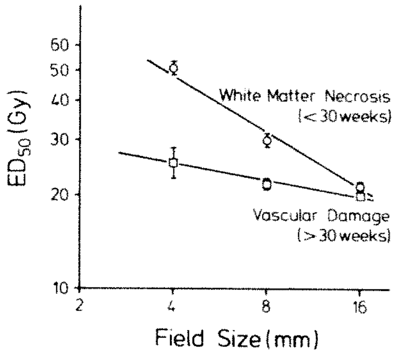


FIG. 6.

Variation in ED_{50} (±SE) for vascular (○) and white-matter (□) related lesions in the rat after the irradiation of 4 mm, 8 mm and 16 mm lengths of cervical spinal cord with single doses of X rays.

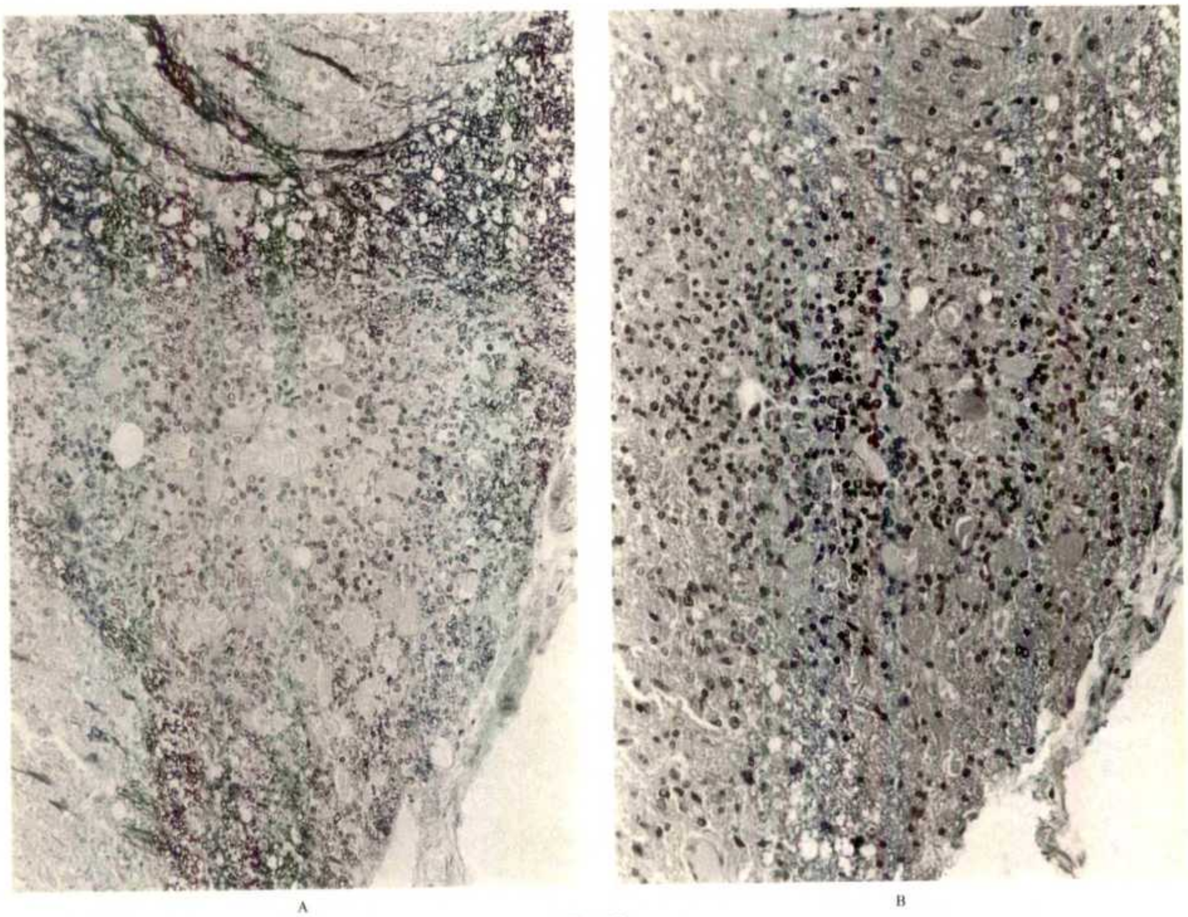


FIG. 7.

Photomicrographs of the dorsal column in a rat developing hind-limb paralysis 78 weeks after irradiation with 30 Gy (4 mm field size). (A) foci of demyelination in the white matter (Luxol Fast Blue PAS × 260; (B) adjacent serial section of the same region of the dorsal column showing an increase in cells with small dark round nuclei (haematoxylin and eosin × 260).

matter. In addition, with doses $\geqslant 24$ Gy to an 8 mm field and $\geqslant 30$ Gy to a 4 mm length of spinal cord, areas of demyelination in the white matter were also noted. These areas were frequently associated with an aggregation of cells with small dark nuclei (Fig. 7). Nerve-root necrosis was also seen in a proportion of the histological sections examined.

In animals that developed paralysis with a latent period of <30 weeks very extensive white-matter necrosis was seen in dorsal, lateral and ventral columns. The severity was apparently greater than that usually associated with doses of 21–24 Gy to a 16 mm length of spinal cord. Telangiectasia was sometimes associated with these extensive areas of necrosis (Fig. 8). Degeneration of small areas of grey matter and demyelination of the nerve roots was also seen after irradiation with doses $\geqslant 39.1$ Gy to a 4 mm length of spinal cord and in those receiving 40 Gy to a 8 mm length of the spinal column. Quadriplegia was frequently associated with these severe lesions in animals in which only 4 mm or 8 mm of the spinal cord had been irradiated.

DISCUSSION

The irradiation of the cervical spinal cord in the rat produced histological lesions that were dependent on both the dose and the length of cord irradiated. The irradiation of 16 mm of cord with doses that resulted in the development of forelimb paralysis in <30 weeks produced selective white-matter necrosis. Necrosis was apparently randomly distributed throughout the length of the irradiated spinal cord and in none of the transverse histological sections examined were there extensive lesions in dorsal, ventral and lateral white-matter columns. These neurological and histological changes are consistent with those reported by others

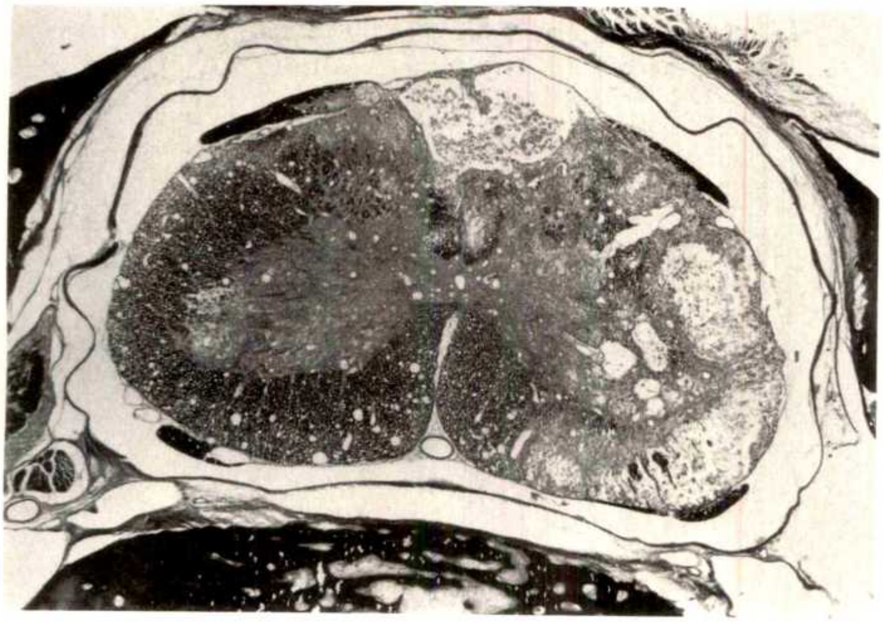


FIG. 8.

Photomicrograph of the cervical spinal cord of a rat developing severe hind- and fore-limb paralysis 29 weeks after irradiation with 32.5 Gy (8 mm field size): transverse section showing demyelination and necrosis of the dorsal, lateral and ventral white-matter columns. Associated with these gross lesions are evidence for partial demyelinisation of the nerve roots and grey-matter lesions. Telangiectatic and dilated blood vessels can be seen (Luxol Fast Blue PAS × 27).

(Hopewell & Wright, 1975; van der Kogel, 1980) as was the observation of an absence of severe nerve-root and grey-matter lesions.

Higher radiation doses were required to produce paralysis in <30 weeks in rats in which 4 mm and 8 mm lengths of spinal cord were irradiated. In these animals the neurological signs were more extensive with both fore- and hind-limbs involved. Histological investigations also showed more extensive damage. In single transverse histological sections that were examined, extensive necrosis of dorsal, lateral and ventral columns was frequently seen. Associated with these lesions were demyelination of the nerve roots and necrosis of the grey matter.

The latter lesions have not previously been reported in the spinal cord of the rat, even after high single doses of 40 Gy (Hubbard & Hopewell 1978; van der Kogel, 1983). Larger fields (16–20 mm) were irradiated in these high-dose studies. Damage to the nerve roots and grey matter may be secondary to the very high extensive white-matter lesions. Radiation-induced spinal root damage is also rare in man, but demyelination has been observed in cases of complete transverse necrosis (Jellinger, 1986).

In animals that survived with a latency of >30 weeks, after the irradiation of 4 mm and 8 mm fields, small foci of demyelination were seen in the white matter. However, these foci were present only after doses which would have resulted in paralysis in <30 weeks, had a 16 mm field been irradiated. These areas of demyelination were associated with increased numbers of cells with small, dark, round nuclei, possibly oligodendrocytes, suggesting an attempted repair process. However, the predominant lesions were vascular and similar to those seen after the irradiation of 16 mm of spinal cord (latent period >30 weeks). These have been described in detail elsewhere for the rat spinal cord (van der Kogel, 1983). Similar lesions have been reported in the rat brain after irradiation (Reinhold & Hopewell, 1980) and in the human spinal cord (Jellinger & Sturm, 1971).

Evidence for a field-size effect relationship for the rat spinal cord was obtained from a comparison of the dose–effect curves with respect to the mean latency for the development of neurological signs. The values for the mean latency obtained in the present study are in very good agreement with those obtained for specific doses in an earlier investigation (Hopewell & Wright, 1975). When animals were subdivided according to the nature of the pathological lesion, no evidence of a dose–latent period relationship was found for the white matter-related lesion, except perhaps for the 4 mm field. This confirms earlier results obtained using this strain of rat (Hubbard & Hopewell, 1978). The same would also appear to hold for radiculopathy or nerve-root damage following irradiation of the lumbosacral cord (White & Hornsey, 1978). However, in some other strains of rat the latency for white-matter necrosis would appear to be dose-related (van der Kogel, 1979). The latency for vascular damage in the spinal cord would appear to be strongly dose-related in most rat strains, even though considerable variability was seen in the present study. This variability has been reported by others (White & Hornsey, 1978; van der Kogel, 1980).

For paralysis developing within 30 weeks, as a result of white-matter necrosis, a clearly defined field-size effect was demonstrated, the ED_{50} value increasing with decreasing field size. A change in isoeffect dose with field size has also been reported in the spinal cord of mice for fields between 6 mm and 12 mm in length and in the rabbit brain when fields 40 mm long were varied in width from 1 mm to 12 mm (Berg & Lindgren, 1963). However, in the brain an increase in the volume also results in major changes in the structures irradiated. Variation in the radiosensitivity of different brain regions, as has recently been demonstrated in the rat brain (Calvo et al, in preparation), would complicate the characterisation of any volume–effect relationship.

The histological changes seen in the spinal cords of animals surviving for >30 weeks after the irradiation of 4 mm and 8 mm of cord with doses that produced necrosis after the irradiation of a larger field, might provide an explanation of the field-size effect relationship for white-matter necrosis. Foci of demyelination were found along with evidence for repair. The large increase in the number of cells with small, dark, round nuclei might represent a migration of cells from adjacent areas of unirradiated spinal cord. Small foci of white-matter damage might be repaired in this way but larger areas, produced by higher doses, might not. The severity of histological lesions, per transverse section, were apparently greater after the irradiation of 4 mm and 8 mm lengths of cord, compared with a 16 mm field, and the animals developed both fore- and hind-limb paralysis.

The migration of cells from the periphery of an irradiated area has been proposed as an explanation of the presence of a field-size effect in pig and mouse skin following the β irradiation of circular fields 5–22.5 mm in diameter (Peel et al, 1984; Hopewell et al, 1986). The ED_{50} for moist desquamation decreased with increasing field diameter. With a larger field (40 mm diameter) the field-size effect was lost; presumably the distance over which the cells had to migrate was too large to influence the acute skin reaction. Very high ED_{50} values (143–275 Gy) were required to produce acute damage to the skin with 1–2 mm-diameter fields. These effects were produced by the direct killing of cells in interphase (Hopewell, 1986). Similar doses, 135–270 Gy, were required to produce lesions in the rabbit brain after the irradiation of narrow, 1 mm- and 2 mm-wide slits (Berg & Lindgren, 1963).

For late degenerative vascular changes in the rat spinal cord, only a small field-size–effect relationship was obtained. Based on the ED_{50} for vascular lesions, the difference in values for 4 mm (25.58 ± 2.78 Gy) and 16 mm fields (20.05 ± 0.5 Gy) only just reach accepted levels of significance. No field-size effect was seen at $\leqslant ED_{25}$. Here again, similarities can be drawn between these results and those obtained for late radiation damage to pig skin (Peel et al, 1985; Hamlet et al, 1986). For a given dose of radiation, from ^{90}Sr plaques, the severity of dermal atrophy after 104 weeks was apparently independent of the diameter of the field irradiated. Fields 5–22.5 mm in diameter were irradiated.

Thus, in the present study it has been demonstrated that a field-size effect exists, at least for relatively small fields, for the white-matter necrosis end-point in the irradiated rat spinal cord. However, the size of field over which this effect might be seen could be limited by the distance over which cells from outside the irradiated zone can migrate and exert an influence. For what would appear to be the most clinically relevant level of effect, a low incidence of late vascular lesions, no evidence of a field-size–effect relationship was seen even for very small fields. However, since both vascular- and white matter-related syndromes are apparently associated with radiation myelopathy in man (Reinhold et al, 1984; Schultheiss et al, 1984), the present experimental findings question current attitudes to the volume factor in the irradiation of the spinal cord of man.

The publication by Abbatucci et al (1978) suggested that the tolerance dose following the irradiation of one to two vertebral bodies (*i.e.* $\leqslant 50$ mm) was greater than that for three to seven vertebrae (*i.e.* $\geqslant 50$ mm). In this study there was no evidence for a marked change in tolerance dose when cord lengths greater than 10 cm were irradiated. This is at variance with the proposal of Boden (1948). While there have been numerous reports on the incidence of myelopathy in man (Wara et al, 1975; Schultheiss et al, 1984), they all deal predominantly with the effects of dose per fraction/fraction number.

To the knowledge of the present authors, details of the length of cord irradiated were given in only one report, in addition to fractionation factors (Reinhold et al, 1976). In this study there were eight cases of myelopathy following the irradiation of $\leqslant 10$ cm of thoracic spine and seven after the irradiation of $\geqslant 12$ cm of the thoracic cord. The mean total dose (TD) and the fraction number (F) associated with these two groups of patients are listed in Table I. Comparable

TABLE I

Data for myelopathy and non-myelopathy patients following radiotherapy that involved the thoracic spinal cord for carcinoma of the lung

Cord length		Myelopathy	Non-myelopathy	p
$\leqslant 10$ cm	TD	62.32 ± 2.06 Gy	60.08 ± 2.4 Gy	NS
	F	24.6 ± 1.7 Gy	25.6 ± 1.1 Gy	NS
	ED	16.23 ± 1.21 Gy	15.39 ± 0.9 Gy	NS
	n	8	12	—
$\geqslant 12$ cm	TD	66.84 ± 1.48 Gy	60.89 ± 2.37 Gy	<0.05
	F	27.9 ± 1.1 Gy	26.4 ± 1.0 Gy	NS
	ED	16.52 ± 0.75 Gy	15.39 ± 0.84 Gy	NS
	n	7	11	—

Calculated from Reinhold et al (1976).

TD = total cord dose; F = fraction number; ED = equivalent dose ($ED = TD/F^{0.42}$); n = number of patients.

Note: ED values were 5.5% ($\leqslant 10$ cm) and 7.3% ($\geqslant 12$ cm) higher in myelopathy patients.

data for non-myelopathy patients, presented by the same authors, are listed for comparison. In each group the average total dose received by myelopathy patients was higher than that for non-myelopathy cases. However, the total dose (TD) and the equivalent effective dose (ED), calculated on the basis of a fraction exponent of 0.42 (van der Kogel, 1980), were not higher for the group which received radiation to $\leqslant 10$ cm of spinal cord; in fact, the reverse was apparently true, although none of the differences were significant.

Further analyses of clinical myelopathy data are clearly required. Additional animal studies are also needed. Of particular interest are those being carried out in large animals in Oxford and Houston, since volumes comparable to those used in man can be irradiated. These studies may finally resolve the problem of the influence of field size on the radiation tolerance of the spinal cord.

ACKNOWLEDGMENTS

The authors are indebted to Mr B. Hopkins and Mrs E. Whitehouse for their technical help and to Miss K. Lane for her care of the animals. The Research Group at the Churchill Hospital is supported by a grant from the Cancer Research Campaign and one of us (A.D.M.) gratefully acknowledges support from the Leukaemia Research Fund during her D.Phil. research studies, of which this work formed a part.

REFERENCES

ABBATUCCI, J. S., DELOZIER, T., QUINT, R., ROUSSEL, A. & BRUNE, D., 1978. Radiation myelopathy of the cervical spinal cord: time, dose and volume factors. *International Journal of Radiation Oncology, Biology, Physics, 4*, 239–248.

BERG, N. & LINDGREN, M., 1963. Relationship between field size and tolerance of rabbit brain to roentgen irradiation (200 kV) via a slit-shaped field. *Acta Radiologica, 1*, 147–168.

BODEN, G., 1948. Radiation myelitis of the cervical spinal cord. *British Journal of Radiology, 21*, 464–469.

CARSTEN, A. & ZEMAN, W., 1966. The control of variables in radiopathological studies on mammalian nervous tissue. *International Journal of Radiation Biology, 10*, 65–74.

DIXON-BROWN, A. & HOPEWELL, J. W., 1988. The calculation of absorbed doses for radiobiological studies involving the use of small irradiation fields. *British Journal of Radiology, 61*, in press.

ELLIS, F., 1942. Tolerance of skin in radiotherapy with 200 kV X rays. *British Journal of Radiology, 15*, 348–350.

GERACI, J. P., JACKSON, K. L., CHRISTENSON, G. M., THROWER, P. D. & MARIANO, M., 1978. RBE for late spinal cord injury following multiple fractions of neutrons. *Radiation Research, 74*, 382–386.

GOFFINET, D. R., MARSA, G. W. & BROWN, J. M., 1976. The effects of single and multifraction radiation courses on the mouse spinal cord. *Radiology, 119*, 709–713.

HAMLET, R., HERYET, J. C., HOPEWELL, J. W., WELLS, J. & CHARLES, M. W., 1986. Late changes in pig skin after irradiation from beta emitting sources of different energy. *British Journal of Radiology, (Suppl. 19)*, 51–54.

HOLDORFF, B., 1980. Dose-effect relationships in cervical and thoracic radiation myelopathies. *Acta Radiologica, Therapy, Physics, Biology, 19*, 271–277.

HOPEWELL, J. W., 1986. Mechanisms of the action of radiation on skin and underlying tissues. *British Journal of Radiology, (Suppl. 19)*, 39–47.

HOPEWELL, J. W., COGGLE, J. E., WELLS, J., HAMLET, R., WILLIAMS, J. P. & CHARLES, M. W., 1986. The acute effects of different energy beta emitters on pig and mouse skin. *British Journal of Radiology, (Suppl. 19)*, 47–52.

HOPEWELL, J. W. & WRIGHT, E. A., 1975. The effects of dose and field size on late radiation damage to the rat spinal cord. *International Journal of Radiation Biology, 28*, 325–333.

HOPEWELL, J. W. & YOUNG, C. M. A., 1982. Effects of field size on the reaction of pig skin to single doses of X rays (letter). *British Journal of Radiology, 55*, 936–937.

HUBBARD, B. M. & HOPEWELL, J. W., 1978. The dose-latent period relationship in the irradiated cervical spinal cord of the rat. *Radiology, 128*, 779–781.

JELLINGER, K., 1986. Radiation-induced lesions in the human central nervous system. In *Boron-neutron Capture Therapy for Tumours*. Ed. by H. Hatanaka (Nishimura, Japan), pp. 125–146.

JELLINGER, K. & STURM, K. W., 1971. Delayed radiation myelopathy in man. Report of twelve necropsy cases. *Journal of Neurological Science, 14*, 389–408.

PALLIS, C. A., LOUIS, S. & MORGAN, R. L., 1961. Radiation myelopathy. *Brain, 84*, 460–479.

PEEL, D. M., HOPEWELL, J. W., WELLS, J. & CHARLES, M. W., 1984. Non-stochastic effects of different energy β-emitters on pig skin. *Radiation Research, 99*, 372–382.

PEEL, D. M., HOPEWELL, J. W., WELLS, J. & CHARLES, M. W., 1985. Late non-stochastic changes in pig skin after β-irradiation. *Radiation Research, 101*, 491–496.

PHILIPS, T. L. & BUSCHKE, F., 1969. Radiation tolerance of the thoracic spinal cord. *American Journal of Roentgenology, 105*, 659–664.

REINHOLD, H. S. & HOPEWELL, J. W., 1980. Late changes in the architecture of blood vessels of the rat brain after irradiation. *British Journal of Radiology, 53*, 693–696.

REINHOLD, H. S., VAN PUTTEN, W. L. J., HOPEWELL, J. W. & VAN DER KOGEL, A. J., 1984. The latent period in clinical radiation myelopathy. *International Journal of Radiation Oncology, Biology, Physics, 10*, 2385–2387.

REINHOLD, H. S., KAALEN, J. G. A. H. & UNGER-GILS, K., 1976. Radiation myelopathy of the thoracic spinal cord. *International Journal of Radiation Oncology, Biology, Physics, 1*, 651–657.

SCHULTHEISS, T. E., 1983. Models in radiotherapy: volume effects. *Medical Physics, 10*, 410–415.

SCHULTHEISS, T. E., HIGGINS, E. M. & EL-MAHDI, A. M., 1984. The latent period in clinical radiation myelopathy. *International Journal of Radiation Oncology, Biology, Physics, 10*, 1109–1115.

VON ESSEN, C. F. 1969., Radiation tolerance of the skin. *Acta Radiologica, Therapy, Physics, Biology, 8*, 311–330.

VAN DER KOGEL, A. J., 1979. Late effects of radiation on the spinal cord. Ph.D Thesis, University of Amsterdam, The Netherlands.

VAN DER KOGEL, A. J., 1980. Mechanisms of late radiation injury in the spinal cord. In *Radiation Biology in Cancer Research*. Ed. by R. E. Meyn & H. R. Withers (Raven Press, New York), pp. 461–470.

VAN DER KOGEL, A. J., 1983. The cellular basis of radiation-induced damage to the central nervous system. In *Cytotoxic Insult to Tissue; Effects on Cell Lineages*. Ed. by C. S. Potten & J. H. Hendry (Churchill Livingstone, Edinburgh), pp. 329–352.

Wara, W. M., Philips, T. L., Sheline, H. E. & Schwayder J. G., 1975. Radiation tolerance of the spinal cord. *Cancer*, *35*, 1558–1562.

White, A. & Hornsey, S., 1978. Radiation damage to the rat spinal cord: the effects of single and fractionated doses of X rays. *British Journal of Radiology*, *51*, 515–523.

1987, *The British Journal of Radiology*, 60, 1109–1117 NOVEMBER 1987

Dose-dependent and time-dependent changes in the choroid plexus of the irradiated rat brain

By W. Calvo, *J. W. Hopewell, †H. S. Reinhold, ‡A. P. van den Berg and *T. K. Yeung

Department of Clinical Physiology and Occupational Medicine, University of Ulm, FDR, *Research Institute (University of Oxford), Churchill Hospital, Oxford, UK, †Radiobiological Institute, TNO, Rijswijk, The Netherlands and ‡Department of Experimental Radiotherapy, Erasmus University, Rotterdam, The Netherlands

(*Received March 1987 and in revised form March 1987*)

ABSTRACT

A histological assessment has been made of both time- and dose-related changes in the choroid plexus after the local irradiation of the rat brain with single doses of 17.5–25 Gy of X rays. These investigations involved the serial killing of animals 1–52 weeks after irradiation and the quantitative and semiquantitative evaluation of histological sections. Counts of the relative number of cells in the choroid plexus of the lateral ventricles showed an atrophy of the epithelial layer after 13 weeks. However, this was not as marked as the reduction in the number of endothelial cells in the wall of blood vessels. Moreover, the epithelium had recovered by 39 weeks after irradiation, while the dose-related depletion in endothelial cells tended to be progressive. A highly correlated group of changes in the vascular-connective tissue was used to produce a numerical "factor". This represented a combined score of radiation damage which was both time- and dose-related. These data suggest that, as an expression of late radiation damage to the choroid plexus, the effect on the endothelium was more important than that to the epithelial cells.

The late-responding normal tissues that limit the fully effective application of radiation in cancer therapy are variable in both their radiosensitivity and the time of onset of clinically recognisable changes. This variability is perhaps not surprising given the complex physiological interrelationships between the different cell types that make up the various tissues. Damage to a specific target cell, or group of target cells, may be modified by little-understood adaptive processes. Thus, the effects assessed will be a reflection of these changes (Hopewell et al, 1986).

Despite this variability in the radiosensitivity and time of onset of clinically detectable damage within these late-responding tissues, various similarities have been found. Vascular abnormalities are nearly always associated with late normal-tissue damage (Rubin & Casarett, 1968) and this has led to the hypothesis that direct radiation damage to blood vessels plays a major role in the development of late tissue effects. However, the term "vascular irradiation damage" would appear to cover a broad spectrum of changes and thus a simple concept of radiation-induced vascular damage, based on a single target cell population, perhaps the endothelium, may represent an over simplification (Hopewell et al, 1986). An opposing view is that "late" radiation injury can result primarily from a depletion of parenchymal cells (*e.g.* Hubbard & Hopewell, 1979; Withers et al, 1980). The results of a recent study in the mouse kidney (Withers et al, 1986), it was claimed, provided additional support for this hypothesis. The value of D_0, obtained from a dose–effect curve, based on counting renal tubules 60–68 weeks after irradiation was found to resemble that of parenchymal stem cells in acutely-responding normal tissues. The slow natural turnover of tubular epithelial cells was also said to account for the delayed appearance of radiation injury to the kidney. However, evidence that D_0 for endothelial cells is in the same range (Reinhold et al, 1985) and that these cells also have a slow natural turnover (Tannock & Hayashi, 1972; Hobson & Denekamp, 1984) should not be ignored. The possibility that some of the vascular lesions seen in irradiated tissue are a secondary reactive change also needs to be considered. However, the circumstances under which this may occur are limited, for example in the kidney as a consequence of radiation-induced hypertension (Asscher, 1964; Wacholz & Casarett, 1970).

At dose levels just above the threshold for the development of late effects in normal tissues there would appear to be a latent, symptom-free period. In this latent period a wide range of morphological, biochemical and physiological changes have been detected. These changes have formed the basis of numerous studies, since these subclinical effects could provide a basis for the understanding of the pathogenesis of detrimental late lesions. For example, the sequence of events that occur in the latent period following the irradiation of the central nervous system has been reported by several authors (Hopewell, 1979; Hornsey et al, 1981; Myers et al, 1986). The effects of irradiation on the rat brain have also been investigated in a multidisciplinary study by members of the European Late Effects Project Group (EULEP). In this study a large number of changes have been demonstrated in the latent period, although some of these have proved to be transient in nature (Gerber

---

Address for correspondence: Dr J. W. Hopewell, Research Institute, Churchill Hospital, Oxford OX3 7LJ.

et al, 1976; Reyners et al, 1982; Keyeux et al, 1983; Hopewell et al, 1986). Eventually, if a given "threshold dose" has been exceeded, radiation damage becomes manifest which, in the rat brain, was characterised by the development of gross vascular abnormalities (Reinhold & Hopewell, 1980), sometimes accompanied by necrosis.

More recently it has been shown that the choroid plexus, in addition to nervous tissue, is affected after local brain irradiation (Calvo et al, 1986). A wide variety of time- and dose-related changes were observed. The choroid plexus of the lateral ventricles represents a relatively simple tissue system in which there is a close association between the vasculature and the epithelial cells, with only a small amount of stromal connective tissue (Tennyson & Pappas, 1968). The detailed morphological changes seen in the various components of the choroid plexus after irradiation have been reported previously (Calvo et al, 1986). The present report provides a quantitative and semi-quantitative analysis of the effects seen after a range of single doses of 17.5–25 Gy of X rays following the serial killing of animals from 1–52 weeks after irradiation.

MATERIALS AND METHODS

A total of 147 3-month-old female Sprague Dawley rats were used in this study. While the animals were under chloral hydrate anaesthesia (300 mg/kg), their brains were locally irradiated with single doses of 17.5, 20.0, 22.5 or 25.0 Gy of X rays. The irradiations were carried out using two parallel opposed 250 kV X-ray units operating at 15 mA with 0.5 mm Cu and 1.0 mm Al added filtration (half value layer 1.3 mm Cu) at a dose rate of 1.3 Gy/min. The brain was irradiated laterally through semicircular ports, 20 mm diameter in 3 mm lead, thereby shielding adjacent, more radio-sensitive structures in the oropharynx. Doses were checked using thermoluminescent dosimetry (TLD) carried out in a frozen rat. This indicated that the variation in dose across the brain was $\sim 4\%$. During irradiations the dose was monitored using a small, 0.1 cm^3, PTW chamber in the X-ray beam close to the head of the rats.

At intervals of 1, 13, 26, 39 and 52 weeks after irradiation, groups of eight animals (at each dose level), plus a comparable group of age-matched control rats, were killed for histological examination. To ensure adequate fixation the animals were deeply anaesthetised with ether and after an initial flushing of the vasculature with 0.9% normal saline, they were perfusion-fixed with Cajal's formol-bromide solution (2% weight/volume ammonium bromide in 14% formalin) for 20 min at a pressure of 110 cm of fixation fluid. The skull was then opened, the brain removed and post-fixed in the same solution for a period of at least 24 h.

The brain was divided along the midline into two equal parts. The right half was used to investigate changes in the choroid plexus of the lateral ventricles. After slicing this half of the brain in the coronal plane, at the level of the optic chiasm, the tissue was dehydrated, cleared and embedded in paraffin wax. Sections, 6 μm thick, were cut and stained with haematoxylin and eosin or luxol fast blue-PAS-haematoxylin. Three to four consecutive sections were stained by each method.

The analysis involved a quantitative evaluation of the density of the epithelial and the endothelial cells as well as a number of semiquantitative assays of specified effects. These effects were scored as being either present or absent on the basis of the histological sections examined for each animal. Hence the incidence of a lesion within a group could be assessed. A detailed description of these effects was given in an earlier publication (Calvo et al, 1986) and only a short outline will be given here.

The epithelial cell density was determined on the basis of the number of cells present in a 600 μm length of epithelial surface. These and subsequent determinations were based on the average of counts obtained from three consecutive sections.

The endothelial cell density was determined in veins and capillaries by counting nuclei around the lumen of 10 blood vessels in each section. Endothelial cell pairs or groups were characterised by two or more adjacent endothelial cell nuclei in an otherwise denuded intimal layer of the blood vessel wall. One hundred "sites" of endothelial cell nuclei were counted in capillaries and veins in consecutive serial sections of the brain. A "site" represented either a single nucleus or an adjacent pair or group of nuclei in the wall of a vessel. Endothelial cells were considered to have an enlarged nucleus when its size was at least twice that of normal.

Epithelial regeneration was characterised by the appearance of multinucleate cells (two to four nuclei) and groups of cells which bulged into the ventricular space with no apparent link with the basement membrane. Regeneration was frequently associated with focal epithelial atrophy.

Fibrosis was one of the features of connective-tissue damage; this included the presence of abundant connective-tissue fibres and a variable number of macrophages between the epithelium and the blood-vessel wall. This typical appearance was associated with a thickening of the basement membrane and degeneration of the tunica media of arterioles.

Oedema of the connective tissue was assumed to be present if a separation of $\geqq 30$ μm (*i.e.* $\geqq$ twice the normal distance) existed between the basement membrane of the epithelium and the blood-vessel wall, provided there was no increase in the amount of fibrous material in this space.

RESULTS

The results of the quantitative evaluation of the number of epithelial and endothelial cells in the choroid plexus are shown in Fig. 1. It is apparent that the effect of irradiation, at the various dose levels, on the cell counts was more severe in the endothelium than in the

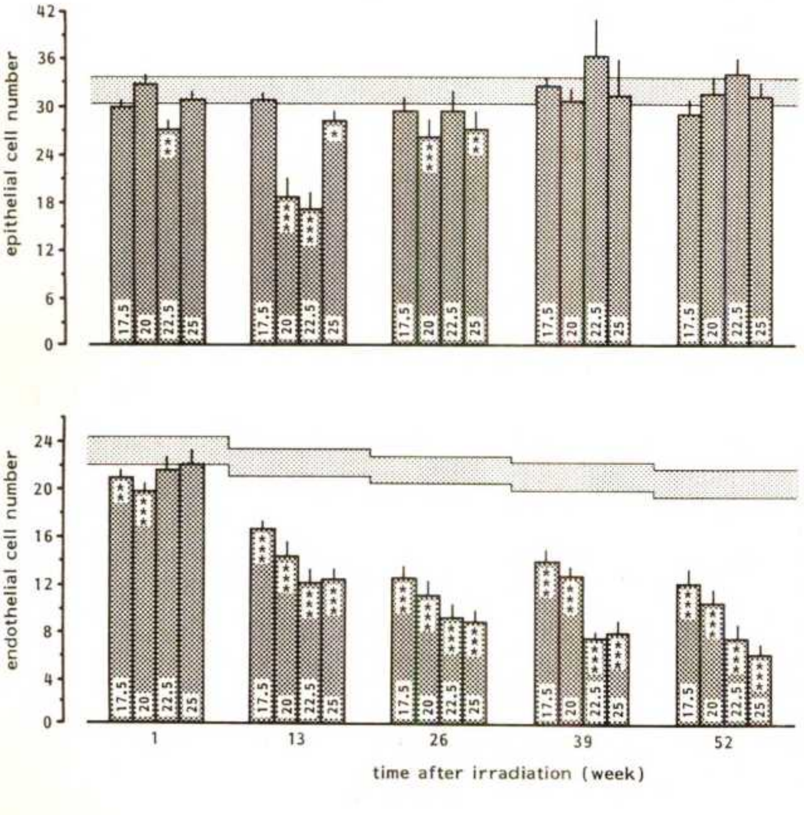


FIG. 1.

Time-related changes in the density of epithelial and endothelial cells in the choroid plexus after irradiation with single doses of 17.5–25 Gy. *y* axis: number of epithelial cells per 600 μm of basement membrane, or endothelial cell nuclei per 10 blood-vessel circumferences. Error bars indicate ± standard error; lightly-shaded area indicates comparable range in unirradiated animals (differences between irradiated and control on the basis of an unpaired Student's *t*-test shown by $**2p<0.01$ or $***2p<0.001$).

epithelium. At 39 weeks and 52 weeks after irradiation the epithelium had apparently recovered. However, at these times the semiquantitative evaluation of the incidence of epithelial cell changes indicated focal areas of atrophy associated with regions of regeneration (Fig. 2). This would help to explain the large standard errors on the mean epithelial cell counts at these times (Fig. 1). At the earlier time of 12 weeks, atrophy of the epithelium was more general after doses of 20–25 Gy, as was indicated by the significant reduction ($p<0.01$) in the epithelial cell density at this time (Fig. 1).

A small fall in the number of endothelial cells was seen as early as 1 week after irradiation; at 13 weeks this reduction had become highly significant at all dose levels ($p<0.001$). Between 26 weeks and 52 weeks the decline in the number of endothelial cell nuclei was dose-related, varying from approximately 40% after 17.5 Gy to approximately 60% after 22.5 Gy and 25 Gy. The distribution of endothelial cells was very heterogeneous, resulting in areas depleted of nuclei alternating with pairs or groups of endothelial cell nuclei. In the brains of unirradiated animals the incidence of endothelial nuclear pairs was very low, 2.6% ± 0.4%. There was a 15-fold increase in the number of nuclear pairs or groups following doses of 22.5 Gy and 25 Gy at 26 weeks. At this and later times the increase in endothelial nuclear pairs or groups in these two doses was higher than after 17.5 Gy and 20 Gy (Fig. 3). Endothelial nuclear enlargement was associated with these pairs or groups of nuclei (Fig. 4).

The results of the different quantitative assessments and semiquantitative evaluations of the incidence of radiation-induced changes in the choroid plexus were compared using the non-parametric Spearman rank correlation test. These comparisons are presented in the form of a correlation table (Table I). A number of strong correlations ($p<10^{-5}$) are apparent in this table.

The physical factors of X-ray dose and follow-up time are listed in Table I. A high correlation with respect to time and dose was found for the reduction in the number of endothelial cell nuclei and the nuclear pairs and groups. Epithelial atrophy expressed either as the number of cells or semiquantitatively as areas of cell loss (Calvo et al, 1986) correlated less well with these physical factors. Epithelial regeneration, on the other hand, was highly correlated with both dose and time.

In view of the very good interrelationship between the various parameters characterising vascular-connective tissue damage (Table I), these parameters were combined into a single damage "factor" using weights obtained by principal component analysis. This "factor" was composed of several phenomena: degeneration of the tunica media of arterioles (weight 0.8), thrombosis (weight 0.73), fibrosis (weight 0.82),

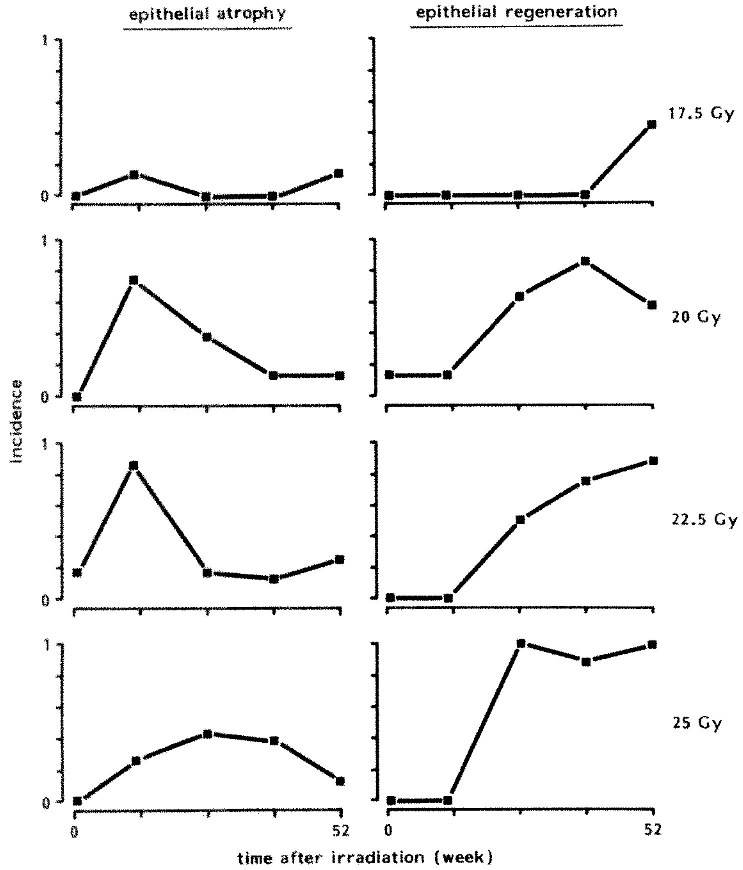


FIG. 2.

Time-related changes in the number of animals (incidence) demonstrating evidence of epithelial atrophy or regeneration in histological sections of the choroid plexus from animals irradiated with single doses of 17.5–25 Gy.

basement membrane thickening (weight 0.81) and presence of phagocytes (weight 0.85). Changes in the value of this "factor", a "combined damage score for vascular-connective changes", as a function of time after irradiation are shown in Fig. 5. It can be seen that the vascular-connective tissue changes increase in severity with X-ray dose and time after irradiation. After a dose of 17.5 Gy it takes over 6 months for damage to develop, after 20 Gy a minor level of damage was apparent from 1 week to 26 weeks and after higher

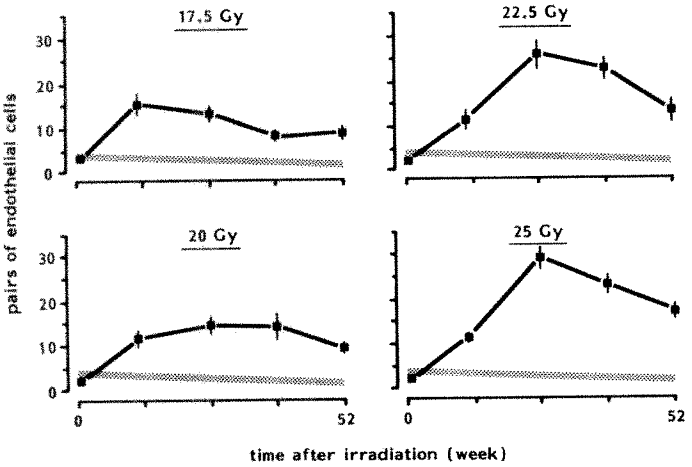


FIG. 3.

Proportion of endothelial nuclear pairs or groups associated with sites of endothelial cells in the vasculature of the choroid plexus 1–52 weeks after irradiation with single doses of 17.5–25 Gy of X rays: Error bar indicates ±standard error; shaded area indicates error in unirradiated control values.

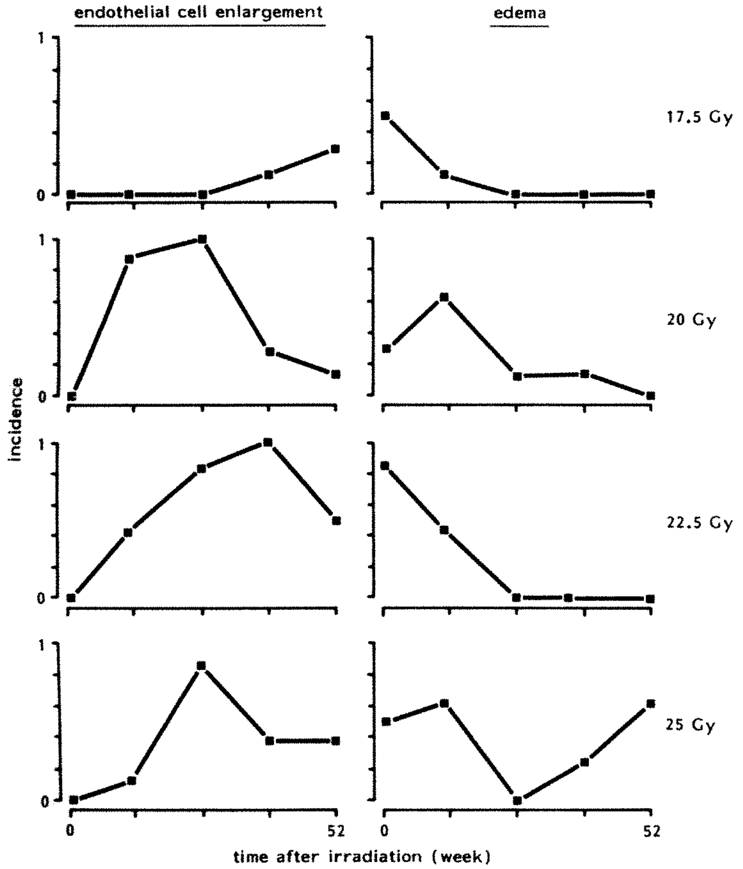


Fig. 4.

Time-related changes in the number of animals (incidence) showing histological evidence of endothelial cell enlargement and oedema, in histological sections of the choroid plexus, after irradiation with single doses of 17.5–25 Gy.

doses (22.5 Gy and 25 Gy) this effect was more obvious. The maximum level of damage to the vascular-connective tissue seems to be reached 39 weeks after 25 Gy.

Oedema of the connective tissue did not correlate with the other connective-tissue changes: it developed very early, even after the lowest dose (17.5 Gy) and tended to decrease with increasing time. The exception was after the highest dose (25 Gy); here the impression was gained that a second wave of oedema developed after 6 months (Fig. 4).

Discussion

The choroid plexus, a delicate tissue structure situated within the ventricular cavity, where it is bathed in cerebral spinal fluid, would appear to represent a simple model in which radiation effects can be evaluated. In the normal unirradiated tissue, the principal cell components, in particular the epithelial and endothelial cells, can easily be identified (Fig. 6A) and counted. Normally there is little supporting stromal tissue between the blood vessels and the overlying epithelium but, as a late consequence of irradiation, this was significantly increased (Fig. 6B), the tissue displaying many of the classic changes associated with late radiation fibrosis (Rubin & Casarett, 1968).

Of the relatively early changes seen in the choroid plexus after irradiation, possibly the most important is the finding that indicates that the endothelial-cell component is more sensitive to moderate doses of radiation than the epithelial-cell component. The maximum reduction in the number of epithelial cells was after 13 weeks, although the changes were not strongly related to dose at this or other times. At later times only qualitative evidence for local epithelial injury was seen along with clear evidence for regeneration. The reduction in endothelial-cell density was more marked after 13 weeks and it persisted and was highly correlated with both dose and time after irradiation ($2p < 0.001$). While not decisively resolving the problem as to the depletion of which cell type is the primary cause of late radiation damage, these observations do appear to differ from those of Withers et al (1986). These authors concluded that late damage in the mouse kidney was primarily from the depletion of parenchymal cells rather than from injury to blood vessels; they claimed a lack of histological evidence of damage to the arterial vasculature at the time the

TABLE I

SPEARMAN RANK CORRELATION COEFFICIENTS (r) FOR THE INCIDENCE OF HISTOLOGICAL PARAMETERS IN THE CHOROID PLEXUS FOR DIFFERENT DOSES AND TIMES AFTER IRRADIATION

	Dose	Time	Epithelial cell density	Epithelial atrophy	Epithelial regeneration	Basement membrane thickening	Fibrosis	Macrophages	Tunica media atrophy	Thrombosis	Oedema	Endothelial cell density	Endothelial cell pairs	Endothelial cell enlargement
Dose	1													
Time	0.05	1												
Epithelial cell density	−0.07	0.21	1											
Epithelial atrophy	0.17	−0.06	−0.65	1										
Epithelial regeneration	0.36	0.57	0.13	0.05	1									
Basement membrane thickening	0.31	0.64	0.22	0.02	0.58	1								
Fibrosis	0.31	0.62	0.22	−0.01	0.56	0.80	1							
Macrophages	0.43	0.44	0.01	0.18	0.55	0.52	0.53	1						
Tunica media atrophy	0.36	0.52	0.08	0.08	0.46	0.51	0.49	0.64	1					
Thrombosis	0.29	0.27	0.04	0.23	0.36	0.41	0.44	0.50	0.54	1				
Oedema	0.16	−0.38	−0.21	0.13	−0.22	−0.15	−0.11	−0.07	−0.10	0.08	1			
Endothelial cell density	0.39	−0.71	−0.05	−0.13	−0.64	−0.60	−0.57	−0.50	−0.51	−0.37	0.30	1		
Endothelial cell pairs	0.30	0.47	−0.03	0.15	0.53	0.36	0.38	0.36	0.36	0.30	−0.20	−0.70	1	
Endothelial cell enlargement	0.22	0.20	−0.05	0.22	0.36	0.26	0.20	0.24	0.12	0.11	−0.09	−0.43	0.49	1

Two-tailed probabilities are: $2p < 0.05$ for $r > 0.16$, $2p < 0.01$ for $r > 0.21$ and $2p < 0.001$ for $r > 0.27$

tubules were initially denuded of epithelium. This may represent a genuine tissue difference, however it should be remembered that there are important physiological differences between these tissues; while the renal parenchyma is solely dependent on the vasculature for a supply of oxygen and nutrients, the epithelium of the choroid plexus can receive these from the circulating cerebral spinal fluid (Wyke, 1969) independently of the vasculature. Moreover, the choroid plexus has a higher labelling index for capillary endothelial cells compared with epithelial cells (Calvo, unpublished) and the initial transient oedema points towards an early primary

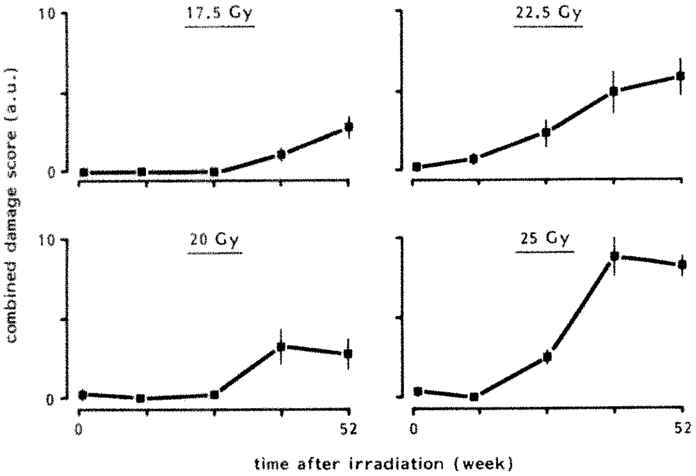


FIG. 5.

Time-related changes in a combined score for damage to the vascular-connective tissue (in arbitrary units) in the choroid plexus after irradiation with single doses of 17.5–25 Gy. Error bars ±standard error.

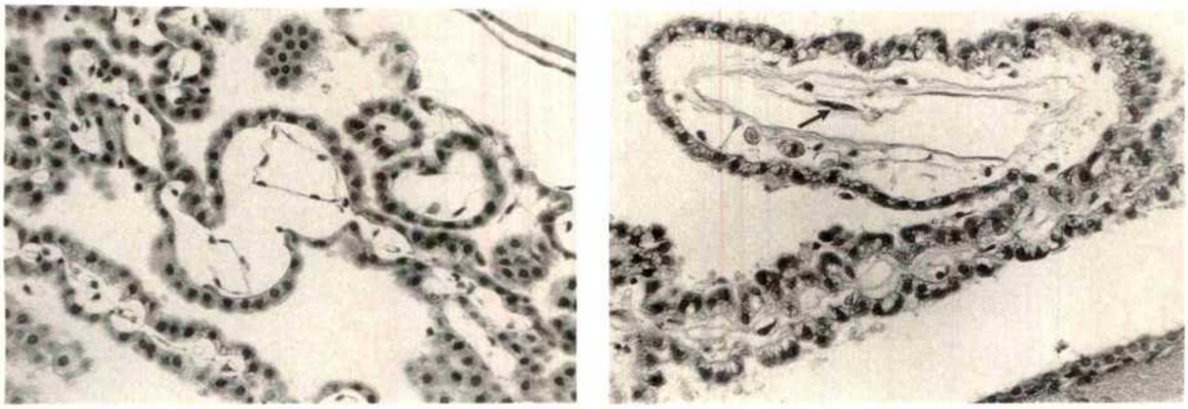


FIG. 6.

Photomicrographs of the choroid plexus in the lateral ventricles of the rat brain (H&E × 190). (A) Normal rat. The epithelium forms garland-like structures with a single layer of cuboidal cells. The capillaries show the normal number, size and regular distribution of endothelial cell nuclei. (B) Choroid plexus of a rat 6 months after 25 Gy. The large vessel in the upper part of the figure has only one very large endothelial cell nucleus (arrow). The increased amount of connective tissue between the vessel and the epithelium contains several phagocytes. In spite of the marked changes present in the vascular-connective tissue, the epithelium shows only minor changes, such as vacuolisation and blebbing.

lesion in the vasculature. Finally the combined score for damage to the vascular connective tissue, which shows strong dose- and time-related changes, was in marked contrast to the conditions found for the epithelium.

In addition to the present data, which provide a strong case for the vascular origins of late radiation damage in the choroid plexus, many of the changes seen in the latent period in this tissue would appear to be similar to those reported by other authors in a broad spectrum of other, often more complex tissues.

The marked reduction in endothelial-cell density seen after 13 weeks has also been reported in the vessels of the heart of rabbits (Fajardo & Stewart, 1971) and rats (Lauk, 1987). Comparable changes were reported in the irradiated cerebral cortex (Caveness et al, 1974). In the arterioles of the mouse mesentery the reduction in endothelial cell number after 13–26 weeks was transient (Hirst et al, 1980) although there was a secondary loss of endothelial cells after 52 weeks. This was attributed to the underlying loss of smooth-muscle cells after this time. Smooth-muscle cell atrophy was seen after a shorter latent period in the choroid plexus, as was reported earlier (Hopewell et al, 1986).

The appearance of groups or pairs of endothelial nuclei in blood vessels showing a reduction in endothelial cell number was taken as evidence for an attempted regeneration. The heterogeneous distribution of the remaining endothelial cells was emphasised by the high proportion of pairs or groups, amounting to 30% of all sites, 26 weeks after 22.5 Gy and 25 Gy. After the administration of ^{3}H-thymidine, the increased number of labelled endothelial cells in the hamster cheek pouch (Campling et al, unpublished) and rabbit heart (Fajardo & Stewart, 1971) was also taken to represent evidence for regeneration in a depleted endothelial-cell population after irradiation.

The long-term effects of a reduction in the number of endothelial cells lining the walls of blood vessels is uncertain, even if a thin cytoplasmic covering of the basement membrane is maintained. However, the appearance of the groups of endothelial cell nuclei which partly or in some cases totally occlude the lumen of vessels would be expected to have an influence on vascular function. Occlusive changes of this type have been reported in numerous tissues and would account for the *in vivo* segmental appearance of irradiated blood vessels in the hamster cheek pouch (Hopewell, 1980), the mouse pinna (Lindop et al, 1969) and the gut mesentery (Hirst et al, 1979). Histological studies have also reported their appearance in the skin, kidney, brain, heart and rectum (for reviews see Hopewell, 1983; Hopewell et al, 1986).

Using various bloodflow techniques, several authors have detected reduced flow in tissue from 12 weeks to 26 weeks after irradiation, for example in bone and bone marrow (Pitkänen & Hopewell, 1983), liver (Keyeux et al, 1971) and pig skin (Moustafa & Hopewell, 1979). In the kidney ^{86}RbCl extraction was significantly reduced by 2 months after 11–19 Gy, the decrease was dose-dependent and preceded histological fibrosis by several months (Glatstein, 1973). This observation would seem directly to contradict that of Withers et al (1986), who reported no histological evidence of damage to the arterial vasculature. Histological evidence of vascular injury was demonstrated to precede the development of myocardial fibrosis in the rabbit heart (Fajardo & Stewart, 1971) and in pig skin, where both histological and bloodflow studies showed evidence for vascular damage at 13 weeks, just prior to the rapid development of dermal atropy between 14 weeks and 20 weeks after irradiation (Hopewell et al, 1986). When severe vascular damage was produced in pig skin after high doses (>20 Gy), ischaemic dermal necrosis resulted. All the above evidence points to the endothelial cell as the target cell involved, at least in part, in the pathogenesis of some radiation-induced change in normal tissues.

Late radiation damage to the choroid plexus consisted of a highly correlated group of changes which included degeneration of the tunica media of the arterioles, basement membrane thickening, fibrosis and thrombosis. These changes occurred earlier and showed the greatest severity 52 weeks after the highest dose of radiation. Whether these changes result from the earlier reduction in the number of endothelial cells or are a direct consequence of radiation damage to smooth-muscle cells is unclear. Hirst et al, (1980) reported degeneration of the tunica media after the apparent repopulation of the endothelium in the gut mesentery, suggesting an independent mechanism. In some tissues, for example the rat heart, cardiac muscle atrophy was associated with degenerative changes in the tunica media of major vessels (Yeung & Hopewell, 1986). Late degenerative changes in the walls of the more major blood vessels are well documented in human radiation pathology and further animal studies are required to establish their likely importance.

ACKNOWLEDGMENTS

This work forms part of the collaborative programme of the European Late Effects Project Group and was partly supported by the Radiation Protection Programme of the Commission of the European Communities, Contract Nos B10-C-345-80-D and B10-E-490-UKH. The Research Institute, Churchill Hospital is supported by the Cancer Research Campaign. The authors would like to thank Miss S. Messenger for her care of the animals and Mrs B. Schnur for the excellent histological preparations.

REFERENCES

Asscher, A. W., 1964. The delayed effects of renal irradiation. *Clinical Radiology, 15*, 320–325.

Calvo, W., Hopewell, J. W., Reinhold, H. S. & Yeung, T. K., 1986. Radiation induced damage in the choroid plexus of the rat brain. A histological evaluation. *Journal of Neuropathology and Applied Neurobiology, 12*, 47–61.

Caveness, W. F., Tanaka, A., Hess, K. H., Kemper, T. L., Tso, M. O. & Zimmerman, L. E., 1974. Delayed brain swelling and functional derangement after X-irradiation of the visual cortex in the Macaca mulatta. *Radiation Research, 57*, 104–120.

Fajardo, L. F. & Stewart, J. R., 1971. Capillary injury preceding radiation induced myocardial fibrosis. *Radiology, 101*, 425–433.

Gerber, G. B., Deroo, J., Bessemans, B., Reinhold, H. S. & Verwey-Versteeg, A. A. C., 1976. Late effects in the central nervous system. A study of biochemical alterations after local exposure of the rat brain to 2kr. *Strahlentherapie, 151*, 530–540.

Glatstein, E., 1973. Alterations in rubidium-86 extraction in normal tissues after irradiation. *Radiation Research, 53*, 88–101.

Hirst, D. G., Denekamp, J. & Hobson, B., 1980. Proliferation studies of the endothelial and smooth muscle cells of the mouse mesentery after irradiation. *Cell and Tissue Kinetics, 13*, 91–104.

Hirst, D. G., Travis, E. L. & Denekamp, J., 1979. The response of mesenteric blood vessels to irradiation. *Radiation Research, 77*, 259–275.

Hobson, B. & Denekamp, J., 1984. Endothelial proliferation in tumours and normal tissues. Continuous labelling studies. *British Journal of Cancer, 49*, 405–413.

Hopewell, J. W., 1979. Late radiation damage to the central nervous system. A radiobiological interpretation. *Neuropathology and Applied Neurobiology, 5*, 329–343.

——1980. The importance of vascular damage in the development of late radiation effects in normal tissues. In *Radiation Biology in Cancer Research*. Ed. by R. Meyn & H. R. Withers (Raven Press, New York) pp. 449–459.

——1983. Radiation effects on vascular tissue. In *Cytotoxic Insult to Tissues. Effects on Cell Lineages*. Ed. by C. S. Potten & J. H. Hendry (Churchill Livingstone, Edinburgh) pp. 228–257.

Hopewell, J. W., Campling, D., Calvo, W., Reinhold, H. S., Wilkinson, J. H., & Yeung, T. K., 1986. Vascular irradiation damage: its cellular basis and likely consequences. *British Journal of Cancer, 53, (Suppl. VII)*, 181–191.

Hornsey, S., Myers, R., Coultas, P. G., Rogers, M. A. & White, A., 1981. Turnover of proliferative cells in the spinal cord after X-irradiation and its relation to time-dependent repair of radiation damage. *British Journal of Radiology, 54*, 1081–1083.

Hubbard, B. M. & Hopewell, J. W., 1979. Changes in the neuroglial cell population of the spinal cord after local X-irradiation. *British Journal of Radiology, 52*, 816–821.

Keyeux, A., Dunjic, A., Rogers, E., Jovanovic, D. & van der Marckt, J., 1971. Late functional and circulatory changes in rats after local irradiation. *International Journal of Radiation Biology, 20*, 7–25.

Keyeux, A., Reinhold, H. S., Hopewell, J. W., Gerber, G. B., Reyners, H. & Calvo, W., 1983. Sequence of events in the development of late irradiation changes in the rat brain. In *Proceedings 7th International Congress of Radiation Research*. Ed. by J. J. Broerse, G. W. Barendson, H. B. Kal & A. J. van der Kogel (Martinus Nijhoff Publishers, Amsterdam), pp. C2–O8.

Lauk, S., 1987. Endothelial alkaline phosphatase activity loss at an early stage in the development of radiation-induced heart disease in rats. *Radiation Research*, in press.

Lindop, P. J., Jones, A. & Bakowska, A., 1969. The effects of 14 MeV electrons on the blood vessels of the mouse ear lobe. In *Time and Dose Relationships in Radiation Biology as Applied to Radiotherapy*. Ed. by V. P. Bond, H. D. Suit & V. Marcual (Brookhaven National Laboratory Report (BNL 50203)), pp. 174–180.

Moustafa, H. F. & Hopewell, J. W., 1979. Blood flow clearance in pig skin after single doses of X-rays. *British Journal of Radiology, 52*, 138–144.

Myers, R., Rogers, M. A. & Hornsey, S., 1986. A re-appraisal of the role of glial and vascular elements in the development of white matter necrosis in irradiated rat spinal cord. *British Journal of Cancer, 53, (Suppl. VIII)*, 221–223.

Pitkanen, M. A. & Hopewell, J. W., 1983. Functional changes in the vascularity of the irradiated rat femur: implications for late effects. *Acta Radiologica, 22*, 253–256.

REINHOLD, H. S. & HOPEWELL, J. W., 1980. Late changes in the architecture of blood vessels in the rat brain after irradiation. *British Journal of Radiology, 53*, 693–696.

REINHOLD, H. S., HOPEWELL, J. W. & BUISMAN, G. H., 1985. Colony regeneration technique in vascular endothelium. In *Cell Clones: Manual of Mammalian Cell Techniques*. Ed. by C. S., Potten & J. H. Hendry (Churchill Livingstone, Edinburgh), pp. 160–169.

REYNERS, H., GLANFELICI DE REYNERS, E. & MAISIN, J. R., 1982. The beta-astrocyte: a newly recognised radiosensitive glial cell type in the cerebral cortex. *Journal of Neurology, 11*, 967–983.

RUBIN, P. & CASARETT, G. W., 1968. *Clinical Radiation Pathology*. (W. B. Saunders Company, Philadelphia.)

TANNOCK, I. F. & HAYASHI, S., 1972. The proliferation of capillary endothelial cells. *Cancer Research, 32*, 77–82.

TENNYSON, V. M. & PAPPAS, G. D., 1968. Choroid plexus. In *Pathology of the Nervous System Vol. I*. Ed. by J. Minckler, (McGraw-Hill, New York), pp. 498–518.

WACHOLZ, B. W. & CASARETT, G. W., 1970. Radiation hypertension and nephrosclerosis. *Radiation Research, 41*, 39–56.

WITHERS, H. R., MASON, K. A. & THAMES, H. D., 1986. Late radiation response of kidney assayed by tubule-cell survival. *British Journal of Radiology, 59*, 587–595.

WITHERS, H. R., PETERS, L. J. & KOGELNIK, H. D., 1980. The pathobiology of late effects of irradiation. In *Radiation Biology in Cancer Research*. Ed. by R. E. Meyn & H. R. Withers (Raven Press, New York), pp. 439–448.

WYKE, B., 1969. *Principles of General Neurology*. (Elsevier Scientific Publications, Amsterdam.)

YEUNG, T. K. & HOPEWELL, J. W., 1986. Histological and physiological studies on rat heart following irradiation with single doses of X-rays. *British Journal of Cancer, 53 (Suppl. VII)*, 196–198.

Book reviews

Organ Doses from Medical X-ray Examinations Calculated Using Monte Carlo Techniques. NRPB, R186. By D. G. Jones and B. F. Wall, pp. 87, 1985 (HMSO, London), £6.00.
ISBN 0–85951–254–1

A National Survey of Doses to Patients Undergoing a Selection of routine X-ray Examinations in English Hospitals. NRPB, R200. By P. C. Shrimpton, B. F. Wall, D. G. Jones, E. S. Fisher, M. C. Hillier, G. M. Kendall and R. M. Harrison, pp. 169, 1986 (HMSO, London), £9.00.
ISBN 0–85951–275–4

An Update on the Frequency of Medical and Dental X-ray Examinations in Great Britain—1983. NRPB, R201. By B. F. Wall, M. C. Hillier and G. M. Kendall, pp. 29, 1986 (HMSO, London), £4.00.
ISBN 0–85951–276–2

These three books are a natural sequence which gives the information to calculate the population radiation dose from X-ray diagnosis in Great Britain. The first, R186, recalculates the organ doses at various kilovoltages and radiographic projections. This has, of course, been done before. This work uses a refinement of the mathematical, Monte Carlo phantom. The allusion to gambling contained within the name arises from the use of random sampling of probability distributions—one million histories were run on the computer for each field so chance must have been defeated. The result gives, compared with earlier studies, a set of data more comprehensive with regard to the list of organ doses, and with an increased number of radiographic projections.

The next publication R200, contains the data of doses to patients already available to readers of the *British Journal of Radiology* (Shrimpton et al, 1986, *British Journal of Radiology, 59,* 749), but here it is in an amplified form, giving details of the dosimetric methods, design of the survey and full results of all measurements.

Lastly, R201 brings up to date the earlier studies assessing the frequency of medical and dental radiography in Great Britain. The frequency of examinations and the expected dose for each examination allow calculation of the annual collective dose to the population in Great Britain from diagnostic radiology—this is now assessed at 17 150 man-Sv, of which medical diagnostic X rays account for 15 500 man-Sv with an additional 500 man-Sv from computed tomography. Dental radiography accounts for 200 man-Sv, and nuclear medicine 950 man-Sv. There is a 2.3% annual increase assessed in the total number of examinations. Intravenous urography and lumbar spine examinations together account for two-fifths of the total population dose. The average population dose of a diagnostic X-ray room in Great Britain works out at a little over 4 man-Sv.

Yet again, very wide variations in the dose for a given examination are found. One can argue that this is to be expected; a barium meal on a neonate is bound to give a much smaller dose than the same examination on a fat adult. It is more difficult to explain the factors of 10 which were found for mean doses for given examinations between two hospitals. We must hope that future studies will analyse these differences and so encourage the trend to lower dose examinations.

The publication of long series of documents from the National Radiological Protection Board means that they tend to be taken for granted. We are very lucky to have these authoritative documents and long may they continue to appear.

J. G. B. Russell

ICRU Report 41. Modulation Transfer Function of Screen-Film Systems. ICRU, pp. vi+56, 1986 (NCRP/ICRU, Bethesda, USA), $16.00.
ISBN 0–913394–35–1

This publication describes the concepts used in the analysis of the physical aspects of radiographic image quality. It provides information about the significance and quantification of radiographic noise and contrast and describes transfer functions that can be used to quantify the resolution properties of imaging systems and their component parts. There are sections on image quality, transfer function analysis, the measurement of modulation transfer function (MTF) and a section which describes factors affecting the MTFs of radiographic screen-film systems. The transfer function analysis is based principally on published articles by Rossman (1969, *Radiology, 93,* 257): this includes descriptions of linearity, shift invariance, point spread function, line spread function (LSF), convolution, MTF and the Fourier spectrum. Although the main text is void of mathematics, there is an appendix in which there are mathematical derivations of the principal functions. There is also a useful glossary where important technical terms are defined, and excellent bibliography and reference sections.

The authors indicate that many techniques have been used to measure the MTFs of screen-film systems but that there are two basic approaches: techniques that use the Fourier transform of the LSF, and those that rely on the measurement of a periodic pattern. Descriptions are given of the slit methods used with digital Fourier transform and analogue Fourier transform respectively, the edge response method, the sine-wave method and the square wave response method. The report notes that good agreement was found in interlaboratory comparisons of MTF measurements on three different screen-film systems using the slit method with digital Fourier transform.

The factors that affect MTF are discussed: these are the cross-over effect that occurs in double-coated X-ray film sandwiched between two screens, X-ray beam quality, oblique incidence effects and the effect of the film cassette.

Whereas many of the basic data in this report can be found in other texts, this publication brings together much of the literature on MTF of screen-film systems and as such it is a very useful booklet to have available for reference. It will find its way into reference libraries, departments of physics, and some departments of radiology!

C. H. Jones

1987, *The British Journal of Radiology*, 60, 1119–1123 NOVEMBER 1987

Technical note

Use of a microcomputer for the estimation of X-ray dose received by the fetus

By D. McG. Clarkson, B.Sc., M.Phil. and S. E. Brennen, B.Sc., M.Sc.

Departments of Medical Physics and Bioengineering, Glan Clwyd Hospital, Bodelwyddan, Clwyd LL18 5UJ and Wrexham Maelor Hospital, Wrexham, Clwyd LL13 7TD

(*Received August 1986 and in revised form February 1987*)

It is a principle of radiological protection that radiation exposure to a fetus should be avoided or minimised. Nevertheless, instances do occur when a fetus is irradiated, for example when a woman's clinical condition requires urgent radiological investigation or when the pregnancy is undiagnosed.

Radiation Protection Advisers are often requested to make an estimate of the dose to the fetus in these cases. The fetal dose is assumed to be equal to the dose to the uterus; this assumption is valid for irradiation in early pregnancy.

The determination of the dose to the uterus is a specific example of organ dosimetry. Organ doses may be determined by: direct measurement at the site of interest; measurement in a phantom (if available); direct measurement at the skin followed by a calculation of dose at depth; or measurement of exposure in the X-ray beam followed by calculation of internal dosage from published data.

For retrospective dose studies, where a phantom is not available, fetal doses can be estimated most easily by the last method. The method uses either central-axis depth-dose data with backscatter factors or tissue–air ratio (TAR) data. The TAR data method has been used as this method is the same whether the organ of interest is exposed to both primary and scattered radiation or only to scattered radiation. The procedure conventionally includes manual calculations which are both time consuming and prone to error. A method using a microcomputer has been developed which allows rapid calculation of fetal dose as a function of incident X-ray spectra and irradiated area.

COMPUTING DETAILS

Programs were written in a version of interpreted Microsoft BASIC configured for use with the CP/M-80 operating system. Extensive use was made of scientific notation for the representation of the spectral energy fractions and TAR contributions in the programs EVESPEC and EVEDOSE. The microcomputer used is a Cromemco CS-2 which, for the application, utilises 64 k random access memory, a Z-80 processor, twin 400 kbyte (k = 1024) mini floppy disk drives, a Televideo 950 visual display unit and a 120 character per s Microline 93 dot-matrix printer. The files SPECDATA and TARDATA are respectively 8 kbytes and 20 kbytes in size. From the time that all relevant data have been entered, a typical printout will be completed in under 2 min. The Microsoft BASIC interpreter, user-programs and data files can all be accommodated on one floppy disk. The version of BASIC used, while not a highly structured implementation, allows the various programs to run essentially without modification on a broad range of microcomputers, both 8-bit and 16-bit. A version which will run on the MS-DOS operating system using Microsoft GWBASIC is also available.

SOURCES OF DATA

X-ray spectra

Published data (Hospital Physicists' Association (HPA), 1979) of 14 commonly used diagnostic X-ray spectra were stored on floppy disk. The kerma spectral data had been converted into fractional exposure per 2 keV interval normalised to 1 R (258×10^{-6} C kg^{-1}) total exposure. Each spectrum was identified by a text description specifying the peak energy and filtration. Table I lists the set of spectra available. The selection of a spectrum in a particular case is based on measurements of kVp and half-value layer of the X-ray beam under the radiographic conditions used for the patient's examination. Data from the spectra were initially written into DATA statements in a BASIC program EVESPEC and then written to a random access file SPECDATA on floppy disk when the program was run. Once the spectra data had been stored on floppy disk they were available for use with the main dose estimation program.

TABLE I

AVAILABLE SPECTRA

Spectrum No.	Description		
	kVcp	Filtration (mm Al)	First half-value layer (mm Al)
1	70	1.5	1.79
2	60	2.0	1.83
3	70	2.0	2.11
4	80	2.0	2.42
5	90	2.0	2.76
6	100	2.0	3.12
7	70	2.5	2.38
8	80	2.5	2.74
9	90	2.5	3.11
10	100	2.5	3.50
11	80	3.0	3.03
12	90	3.0	3.43
13	100	3.0	3.85
14	120	2.5	4.31

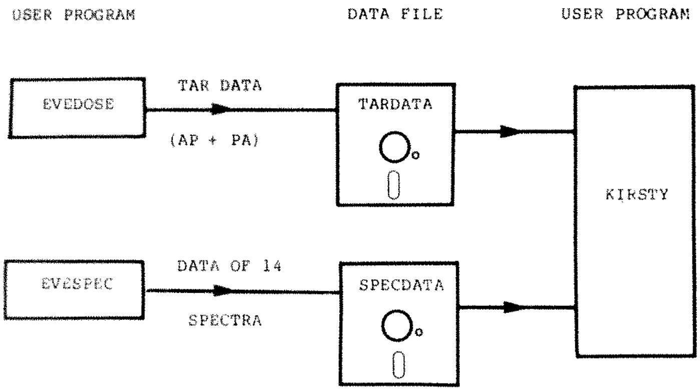


Fig. 1.

Summary of structure of user-program and data relationships.

Tissue–air ratios

The TAR is the absorbed dose in tissue per unit exposure (free in air) at the organ reference plane in units of rad/R. The TAR values describe the deposition of energy from the applied radiation to the organs of a mathematical phantom by the Monte-Carlo analysis of photon interactions. The TAR values used are from published data (US Department of Health, Education and Welfare (USDHEW), 1976) which are specific to the phantom described in the publication. The phantom is subdivided into a matrix of body compartments of 4 cm × 4 cm. The TAR values are tabulated for the indicated body compartments at various energies. Because of the "mirror image" symmetry of the grid system about the central "spine", the 288 individual grid elements can be characterised by only 161 elements. Separate sets of data are available for each of the postero-anterior (PA), antero-posterior (AP) and lateral beam geometries, though only PA and AP were used in this instance. Values of TAR are quoted at energies of 20 keV, 25 keV, 30 keV, 55 keV, 80 keV and 100 keV. For the various body compartments irradiated it is necessary to sum these TAR values at each energy value. The TAR values were initially contained in DATA statements in a BASIC program EVEDOSE and were transferred to a random access file TARDATA when the program was run. Once the respective spectrum data and TAR data had been correctly established on disk, there was no further requirement to run the EVEDOSE and EVESPEC programs.

The TAR is defined in terms of the traditional radiation quantities of dose per exposure and expressed in units of rad/R. This article and the program follow this convention, merely converting the final fetal dose to SI units of absorbed dose (Gy).

Main Application Program

KIRSTY

With the set of X-ray spectra data and TAR data held on floppy disk, the BASIC program KIRSTY was used to calculate the relevant fetal dose factor. Figure 1 summarises the initial process of creation of the data files and the use made of them by KIRSTY. After input of patient identification details, the user specifies which of the available X-ray spectra is to be used. The user then inputs the tube output at the uterus plane in R and selects which beam geometry (AP or PA) is required. The user next specifies which body compartments have been irradiated. Factors of $2, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}$ and $\frac{1}{16}$ can be selected for each 4 cm × 4 cm compartment in order to quantify the field of X-ray exposure more clearly. The smallest area thus able to be defined is 1 cm^2. Details of selected compartments and associated factors can be displayed or listed in the final output of the program.

After the user has specified whether the output from the program should be printed or displayed, the process of evaluation of the fetal dose commences. Figure 2 outlines the various stages in the process of configuring a series of calculations using KIRSTY and also describes the associated stages of preparation required before data can be entered in the correct form for computer input.

Dose calculation

Initially the TAR data are accessed on disk to determine the total contribution to the fetal dose arising from irradiation of body compartments at each of the six discrete keV energies between 20 keV and 100 keV. The TAR values at 2 keV intervals are estimated using a curve-fitting process operating on the logarithm of TAR values at each of the discrete energies. The method used involves three separate curve fits of up to four points using a simple cubic function. Linear fitting between pairs of points tends to give values as much as 10% lower than optimally fitted profiles. The TAR values at energies above 100 keV (Spectrum 14) are assumed to be equal to that at 100 keV. When low-energy contributions are absent from the series of energies between 20 keV and 100 keV, the program reports such points as being absent from the main series and extrapolated values derived from the remaining points are used. The problem of "missing" low-energy

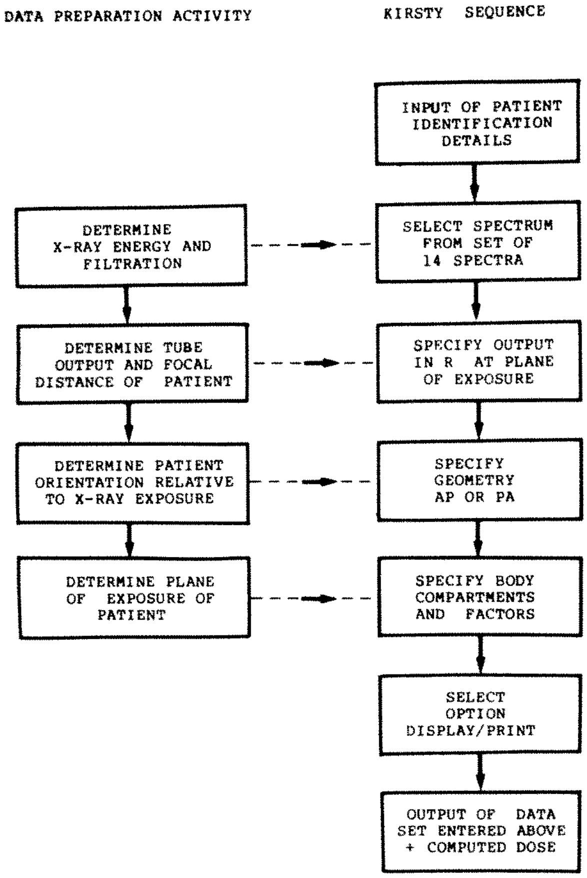

DATA PREPARATION ACTIVITY
KIRSTY SEQUENCE
INPUT OF PATIENT IDENTIFICATION DETAILS
DETERMINE X-RAY ENERGY AND FILTRATION
SELECT SPECTRUM FROM SET OF 14 SPECTRA
DETERMINE TUBE OUTPUT AND FOCAL DISTANCE OF PATIENT
SPECIFY OUTPUT IN R AT PLANE OF EXPOSURE
DETERMINE PATIENT ORIENTATION RELATIVE TO X-RAY EXPOSURE
SPECIFY GEOMETRY AP OR PA
DETERMINE PLANE OF EXPOSURE OF PATIENT
SPECIFY BODY COMPARTMENTS AND FACTORS
SELECT OPTION DISPLAY/PRINT
OUTPUT OF DATA SET ENTERED ABOVE + COMPUTED DOSE

Fig. 2.

Schematic diagram of sequence of operating the main program KIRSTY, indicating associated data-preparation activity.

points is more likely to occur with "scatter" estimations where the fetus has not been directly irradiated. It is unlikely, however, that for these exposures the fetal dose will be significant.

The dose contribution to the fetus at a specific energy is the product of the TAR contribution at that energy and the corresponding fractional spectum energy, values of the latter being obtained from the file SPECDATA. The total dose is therefore calculated by summing all the contributions over the range of contributing spectral energies. Spectrum fraction, TAR contribution and corresponding calculated dose values are listed or displayed in 2 keV intervals for all relevant energies.

The fetal dose is calculated by multiplying the summed spectrum-modulated TAR value by the previously entered value of the exposure in air at the uterus plane, determined by tube output measurements. For most examinations, a number of radiographs and views are taken. KIRSTY is rerun for each exposure.

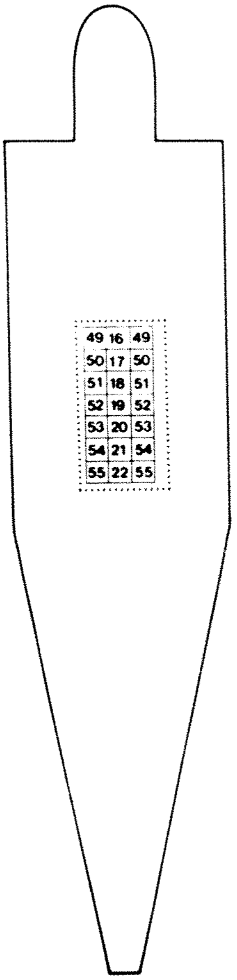


Fig. 3.

Schematic representation of irradiated area for lumbar spine example.

Example: Lumbar Spine

Figure 3 outlines a region of interest (dotted lines) with the X-ray field centred on L4, at the iliac crest, slightly off midline. For clarity, only "whole" compartments within the region of interest are identified numerically.

Table II summarises the user-determined parameters and calculated values for the lumbar spine example. Figure 4 illustrates for this example the relative contribution to the fetal dose of the X-ray spectra and associated TAR values.

In Table III, the fetal dose in the example has been compared with the dose estimated by other methods including a simple phantom measurement. Percentage depth dose (PDD) data, backscatter factors (BSFs) and TARs used in the calculations are from the published sources identified.

TABLE II

PARAMETERS OF LUMBAR SPINE EXAMPLE*

Tube output at uterus plane	0.183 R
Spectrum-modulated TAR value	0.3705 rad/R
Uterus dose	67.8 mrad (0.678 mGy)

*For a spectrum of 80 kVcp, 3.1 mmAl filtration and first half-value layer 3.0 mmAl.

DISCUSSION

All retrospective dose estimations rely on reproducing, as accurately as possible, the conditions of the examination involving a phantom.

The inaccuracies fall into two categories. Firstly, differences between the phantom and the individual patient: the patient's size may vary from the average, and size and position of the uterus may vary and as pregnancy progresses will change significantly. Errors of this nature are common to all methods of retrospective dose estimation involving a phantom. Secondly, there are variations in an individual hospital's technique for conducting particular examinations. These include differences in the number of radiographs and their location, in beam geometry, *i.e.* field sizes, centring etc., and in exposure factors. This method allows considerable flexibility for variations in technique to be taken into account. The positioning of the irradiated area can be defined within 1 cm, which is particularly important when the beam edge lies close to the position of the fetus.

In the example, the measured equipment data correspond very closely with Spectrum 11. However, there may be errors in the choice of spectrum closest to the measured data; there are differences of up to 15% between adjacent spectra. Also a small degree of variability will be introduced by the process of curve-fitting itself.

From Table III, all the methods of calculation yield results within 10% of the mean value. The phantom measurement is significantly below the other values. When the geometry of the phantom was investigated further, it was found that the point of measurement approximating to the position of the uterus was at a depth of 10.8 cm compared with a value of 8.0 cm used in the mathematical phantom and other calculations. The difference in depth dose between the depths accounts for the difference in the measurement.

TABLE III

COMPARISON OF METHODS

Method	Fetal dose (mGy)
This method (TAR)	0.679
Calculation: PDD+BSF	0.766*
Calculation: PDD+BSF	0.718†
Calculation: TAR	0.682‡
Measured entrance dose	
Calculation: PDD	0.632
Measured fetal dose	0.43

*British Institute of Radiology (1972).
†Harrison (1981, 1982).
‡National Council on Radiation Protection and Measurements (1977).

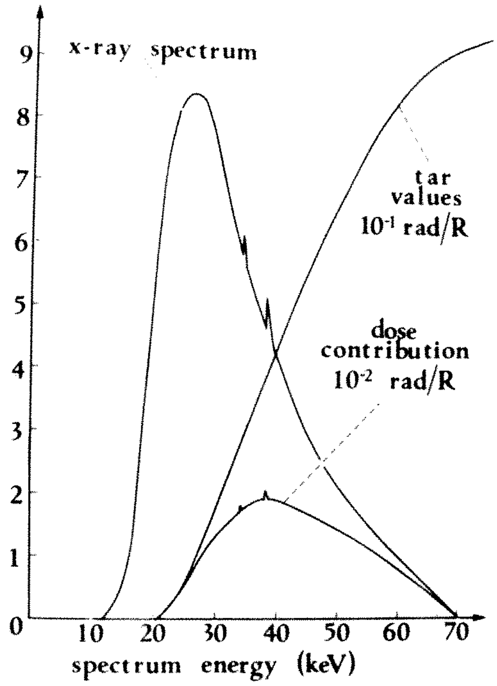


FIG. 4.

X-ray spectrum, TAR values and corresponding fetal dose contribution for lumbar spine example.

When circumstances require an estimate of fetal dose to be determined the result is usually needed with some urgency. Hence the use of this set of programs allows rapid calculation to be made when the experimental data have been measured, and the beam geometry determined.

ACKNOWLEDGMENTS

We would like to thank the Mersey Regional Radiation Protection Service for loan of the phantom and for thermoluminescent dosimetry, and Mr C. P. Double for help with the practical measurements used in the example.

REFERENCES

BRITISH INSTITUTE OF RADIOLOGY, 1972. *Central Axis Depth Dose Data for Use in Radiotherapy.* British Journal of Radiology Suppl. 11 (British Institute of Radiology, London).

HARRISON, R. M., 1981. Central-axis depth-dose data for diagnostic radiology. *Physics in Medicine and Biology, 26,* 657–670.

——1982. Backscatter factors for diagnostic radiology (1–4 mm Al HVL). *Physics in Medicine and Biology*, *27*, 1465–1474.

HPA, 1979. *Catalogue of Spectral Data for Diagnostic X-Rays.* Scientific Report Series 30. Ed. by R. Birch, M. Marshall & G. M. Ardran (HPA, London).

NCRP, 1977. *Medical Radiation Exposure of Pregnant and Potentially Pregnant Women.* NCRP Report No. 54 (NCRP, Maryland).

USDHEW, 1976. *Organ Doses in Diagnostic Radiology.* HEW Publication (FDA) 76–8030. Ed. by M. Rosenstein (USDHEW, Rockville, Maryland).

Book reviews

Biochemical Mechanisms of Platinum Antitumour Drugs. Ed. by D. C. H. McBrien and T. F. Slater, pp. 423, 1986 (IRL Press Ltd, Oxford), £35.00.
ISBN 0-947946-47-0

This book sets out to record the proceedings of a symposium held at Brunel University in July 1985 on the biochemical actions of platinum antitumour drugs. There are five sections, each consisting of several presentations, discussing antitumour activity, metabolism, renal toxicity, the clinical application of platinum compounds and analytical techniques. In general each of these topics is well represented, although from a clinical point of view it is somewhat disappointing to see only a single contribution in the section on the clinical application of platinum compounds. However, this is somewhat tempered by the other sections which have considerable clinical relevance, such as methods to modify the nephrotoxic action of cisplatin. On the whole the book appears to be aimed at both clinical and experimental workers involved in the study and use of platinum antitumour drugs.

Despite being a multiauthor work there is very little repetition in the text, which is clear and easy to read. However, since these proceedings have been produced quickly, the overall style of presentation is characteristic of a rapidly prepared and edited text, with a number of spelling errors. Against these minor criticisms it should be noted that at the end of each chapter there is a discussion by the participants which often proved very interesting. Indeed, in some respects these discussions proved to be one of the best features of the book, as the reader is introduced to the general concepts behind the individual presentation plus many new ideas generated by the participants.

The book is priced at £35, and represents good value for money. Although some parts are somewhat dated, particularly the clinical survey of new compounds, the majority of the problems discussed remain problems, and thus this book will be of considerable use to workers in the field of platinum antitumour drugs. Since the book covers the whole area of research into platinum antitumour drugs it is unlikely that an individual would consider buying it for personal use, but as a reference book, for purchase by a departmental library, it is highly recommended.

M. E. Robbins
A. C. Jones

Physical Techniques in Clinical Hyperthermia. Ed. by J. W. Hand and J. R. James, pp. xviii + 558, 1986 (Research Studies Press, England), £59.95.
ISBN 0-86380037-8

This is an interesting book. Generally, the editors have succeeded in their aim to produce a text which reflects the current state of physics in hyperthermia and which will be useful for physicists, engineers and clinicians working in the field. Most of the important physical topics in hyperthermia are covered, but one surprising omission is the measurement of blood flow rate.

In the introduction, the editors present a realistic and up-to-date view of the field, paying due attention to the severe technological problems which still remain to be solved. A brief résumé is given of all the topics covered in detail later in the book. There are excellent chapters by Bach Andersen, Strohbehn et al and Strohbehn and Mechling which begin with simple concepts in electromagnetism and, with very clear explanations, build up to an analysis of practical hyperthermia systems. Good discussions of radiating applicators are to be found in the chapters by Hand and Hind and James et al, and a well written account of thermography is given in the chapter by Jones and Carnochan. The chapters on ultrasound and clinical hyperthermia systems are inclined to be turgid with some distractions from the main theme. This is also true of the theoretical chapter on electromagnetic heating and radiometry by Bardati which is also particularly inaccessible for the newcomer to the subject.

The varying typeface throughout the book is slightly disconcerting when browsing from chapter to chapter, and it is unfortunate that a particular typeface was not stipulated before the individual authors prepared their camera-ready manuscripts. There is much repetition within the book, which perhaps is to be expected in any collection of independent contributions on a subject. For example, explanations of the bioheat transfer equation and the formula for calculating specific absorption rate each appear no fewer than four times.

Overall, however, the book contains much useful information and will encourage a wider understanding of the physics of hyperthermia. It is to be recommended for the library of any centre engaged in the development of clinical hyperthermia.

H. Griffiths

1987, The British Journal of Radiology, 60, 1125–1126 NOVEMBER 1987

Case reports

A case of mitozantrone-associated cardiomyopathy without prior anthracycline therapy

By G. R. Pai, M.R.C.P., *N. S. Reed, M.R.C.P., F.R.C.R. and W. S. J. Ruddell, M.D., F.R.C.P.

Department of Medicine, Falkirk & District Royal Infirmary and *Glasgow Institute of Radiotherapeutics & Oncology

(Received December 1986 and in revised form May 1987)

Mitozantrone, an anthracene dione, is structurally related to, but claimed to be less cardiotoxic than, doxorubicin (Crossley, 1983). Most of the cases of cardiac failure attributed to mitozantrone have received prior doxorubicin therapy, which is the most important factor predisposing to cardiotoxicity (Crossley, 1983). We report a case of diffuse myocardial disease associated with the administration of mitozantrone alone.

CASE REPORT

A 44-year-old lady presented in June 1985 with dyspnoea of 1 week's duration. In March 1983 she underwent wide local excision for a spheroidal cell carcinoma of the left breast and was treated with radical megavoltage radiation therapy to the left breast and lymphatic drainage areas. This was a three-field technique with tangential fields to the breast giving 4600 cGy t.d. in 23 fractions over a month and 4930 cGy incident doses over the same period of time to the anterior left supraclavicular and axilliary regions. A boost to the primary tumour site and scar was given with 10 MeV electron beam therapy to a dose of 1500 cGy incident dose in five fractions over a week. Radiation treatment was tolerated uneventfully. The estimated dose to the left ventricle was under 30% of the tumour dose delivered to the breast.

In July 1984, multiple spinal metastases were noted and she was treated initially by palliative radiotherapy and, in view of the rapid relapse of her disease, treatment with cytotoxic agents was commenced. She was put on a 3-weekly regime of vincristine 1.4 mg/m^2, mitozantrone 14 mg/m^2 and prednisolone 25 mg b.d. She received nine courses of chemotherapy, with a total dose of mitozantrone of 165 mg, finishing in March 1985.

On admission she was orthopnoeic, with grossly raised jugular venous pressure, regular tachycardia of 130/min, blood pressure 110/70 mm Hg, loud third heart sound, and clear lung fields. There were no murmurs; liver was palpable and pulsatile 4 cm below the right costal margin and was tender. There was minimal pitting oedema. Chest radiography showed moderate cardiomegaly and an electrocardiogram showed non specific ST-T changes. An echocardiogram showed a dilated, poorly contracting left ventricle, normally functioning valves and no regional wall motion abnormalities.

She responded promptly to digoxin and frusemide and was discharged home after a week. She discontinued treatment after 3 weeks, as she felt well. However, when seen 2 weeks later, she remained asymptomatic, but had a recurrent sinus tachycardia and a month later was having supraventricular tachycardia at 180/min and was persuaded to restart digoxin and diuretics. Nine months later, she continues to have exertional dyspnoea, moderate cardiomegaly, a prominent third heart sound and sinus tachycardia at 110/min.

She has now been off chemotherapy for about a year and has had a remarkable continued response with no evidence of tumour progression or symptomatic relapse.

DISCUSSION

Mitozantrone is an anthracene dione and, unlike anthracyclines, lacks the amino–sugar group, which is thought to be responsible for cardiotoxicity (Crossley, 1983). Anthracycline cardiotoxicity probably occurs through generation of super oxides and lipid peroxidation. This may be reduced with mitozantrone, which has little propensity for free-radical formation (Crossley, 1983).

Though adverse cardiac events have been reported with mitozantrone, most patients have received prior doxorubicin treatment. Foster et al (1984) reported four cases of congestive cardiac failure out of 633 patients treated with mitozantrone and all had prior doxorubicin.

Of 766 patients entered in the mitozantrone protocol by the South Eastern Cancer Study Group, there were 66 cardiac events (eight reduced ejection fraction, five atrial and ventricular arrhythmias, one myocardial infarction, one congestive cardiac failure and one first-degree heart block). The lone patient with cardiac failure had not received any doxorubicin (Gams & Wesler, 1984). The single patient with cardiac failure reported by Unverferth et al (1983) received a very large dose of mitozantrone (208 mg/m^2 body surface area). Stuart-Harris et al (1984) report two cases of cardiac failure out of 62 patients with carcinoma of the breast treated with mitozantrone. These patients did not receive prior doxorubicin, but had prolonged treatment with mitozantrone (11–13 months).

This patient is unusual in that she developed dilated cardiomyopathy with a relatively small dose of mitozantrone without prior cardiotoxic chemotherapy. However, she had received megavoltage irradiation to the left breast and although there was no evidence of radiation fibrosis of the lung, it has been suggested that prior radiotherapy increases the risk of cardiotoxicity after mitozantrone (McDonald et al, 1984).

REFERENCES

Crossley, R. J., 1983. Clinical safety and tolerance of mitozantrone (Novantroen*). *Cancer Treatment Reviews*, *10 (suppl. B)*, 29–36.

Foster, B. J., Bergemann, C. & Marsoni, S., 1984. Cardiac events in phase II trials with mitozantrone. *Cancer Treatment Symposia*, *3*, 43–46.

Gams, R. A. & Wesler, M. J., 1984. Mitozantrone cardiotoxicity: results from South Eastern Cancer Study Group. *Cancer Treatment Symposia*, *3*, 31–33.

McDonald, M., Posner, L. E., Dukart, G. & Scott, S. C., 1984. A review of the acute and chronic toxicity of mitozantrone. *Drugs under Experimental and Clinical Research*, *11*, 745–752.

Stuart-Harris, R. C., Bozek, T., Pavlidis, N. A. & Smith, I. E., 1984. Mitozantrone: an active new agent in the treatment of advanced breast cancer. *Cancer Chemotherapy and Pharmacology*, *12*, 1–4.

Unverferth, D. V., Unverferth, B. J., Balcerzak, S. P., Bashore, T. A. & Neidhart, J. A., 1983. Cardiac evaluation of mitozantrone. *Cancer Treatment Reports*, *67*, 343–350.

Asymmetrical pulmonary oedema due to Swyer-James syndrome

By E. A. Vanker
Department of Cardio-thoracic Surgery, University of Natal and Wentworth Hospital, Durban, South Africa

(*Received February 1986*)

Unilateral pulmonary oedema is an uncommon condition, often causing difficulty in diagnosis. An underlying pulmonary abnormality can either predispose to the development of pulmonary oedema or protect against it. Calenoff et al (1978) have identified at least 18 clinical situations in which unilateral pulmonary oedema was a feature. There have been two previous reports of unilateral pulmonary oedema in association with Swyer-James syndrome (Saleh et al, 1974; Bhaskar et al, 1980). This is belived to be the first report of Swyer-James syndrome of lobar distribution protecting against pulmonary oedema.

Case Report

A 13-year-old Asiatic boy, known to have rheumatic heart disease, presented in hospital in severe congestive heart failure. He had undergone mitral valve replacement 30 months earlier, and was diagnosed as having a severely stenotic, calcified porcine xenograft. He had the clinical features of mitral stenosis with finger clubbing, a pulse of 120 per min and blood pressure of 100/60. There was marked jugular venous distension, with crepitations throughout the right side of the chest and the left upper zone and there were diminished breath sounds on the left side posteriorly.

The chest radiograph on admission confirmed the physical findings of pulmonary oedema which spared the left lower lobe (Fig. 1). This lobe was of normal size, but lacked vascular markings, especially peripherally.

The radiographic changes rapidly cleared on antifailure therapy (Digoxin, frusemide). Review of subsequent radiographs and of those taken before he was in cardiac failure confirmed a transradiant left lower lobe (Fig. 2). On fluoroscopy the lobe hyperinflated on inspiration, with airtrapping during expiration causing paradoxical movement of the mediastinum.

When the patient was clinically better, cardiac catheterisation was undertaken at which the mitral valve area was calculated as 0.5 cm^2; the cardiac output was 2.7 l per min and the pulmonary venous pressure was 16 mm of mercury. A bronchogram demonstrated bronchiectasis in a normal-sized left lower lobe with the characteristic bronchiolitis obliterans of Swyer-James syndrome (Swyer & James, 1953) (Fig. 3). There was delayed washout of radioactive xenon and a technetium scan showed markedly diminished perfusion to the left lower lobe (Fig. 4).

Discussion

Unilateral transradiancy from other causes affecting a lung or a lobe is not uncommon in our experience. Swyer-James syndrome is probably an acquired condition attributed to childhood bronchiolitis and bronchiolitis obliterans with dilatation and destruction of lung parenchyma, which can occur in a varying anatomical distribution within the lung. There is usually a history of repeated respiratory tract infection in childhood (Reud & Simon, 1962). The basic aetiology is likely to be infection, perhaps adenovirus (Macpherson et al, 1969) or, in this instance, tuberculosis producing temporary bronchial obstruction from grandular enlargement or endobronchial tuberculosis (Macleod, 1954).

Radiographically, there is a significant difference between the transradiancy of the affected lung compared with the remaining parts. Decreased peripheral lung markings indicate attenuation of vessels with diminished branching (Saleh et al, 1974). The ipsilateral hilum is small. Bronchography shows the characteristic deformity of the bronchial tree, with segmental bronchi irregularly dilated and ending abruptly in squared or tapered configuration of the fifth or sixth divisions.

The capillary bed in the affected lung is destroyed

Address for correspondence: Department of Cardio-thoracic Surgery, Wentworth Hospital, Private Bag JACOBS 4026, Durban, Natal, South Africa.

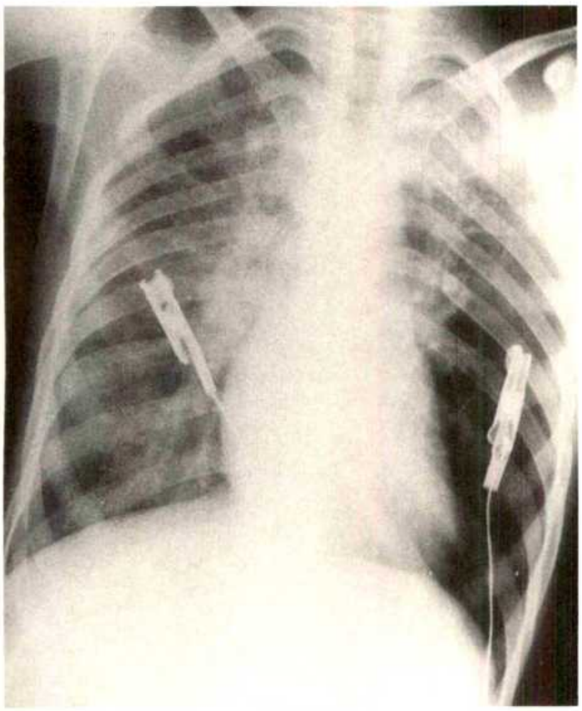


FIG. 1.
Chest radiograph taken on admission.

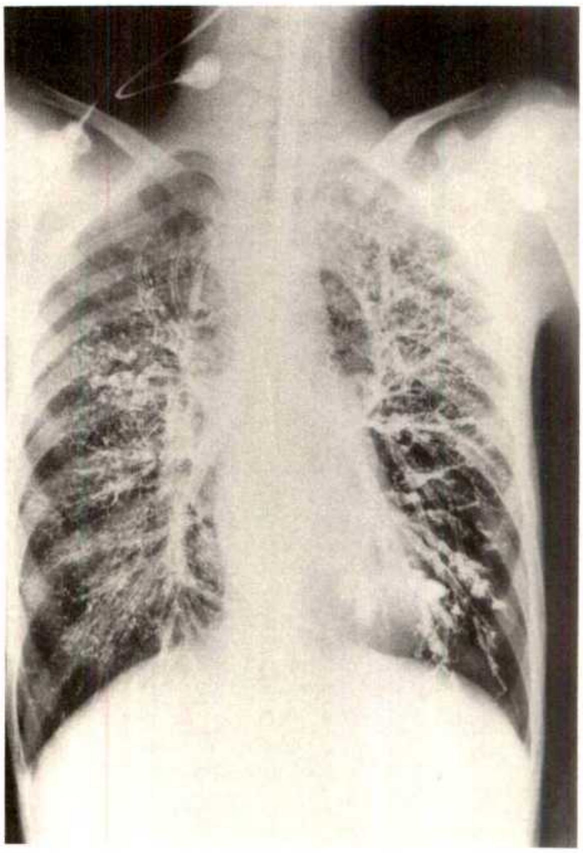


FIG. 3.
Antero-posterior bronchogram.

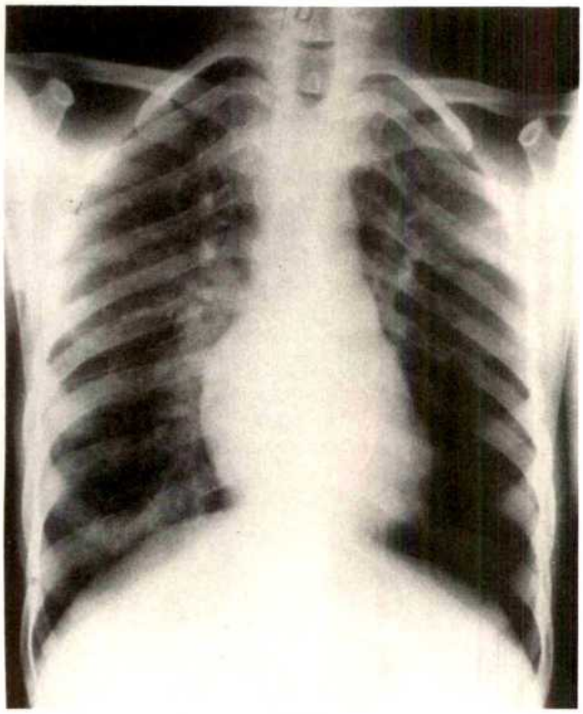


FIG. 2.
Radiograph taken after treatment for pulmonary oedema.

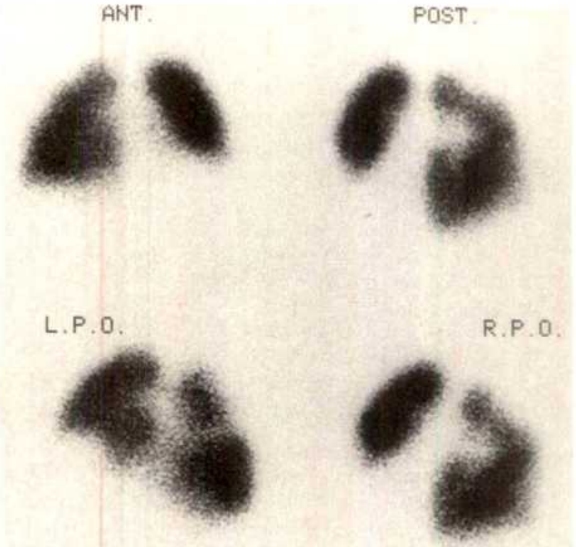


FIG. 4.
Perfusion scan.

and this underperfusion is thought to be the basis for failure of pulmonary oedema to develop (Heitzman, 1976). It is possible that parenchymal destruction and fibrosis interferes with the normal pathway of fluid transudation in pulmonary oedema (Cottrell et al, 1967). Alveolar fluid during the alveolar flooding phase of hydrostatic pulmonary oedema is known not to cross the alveolar capillary membrane, but to arise from the vessels at the level of the terminal bronchioles (Cottrell et al, 1967; Hurley & Jago, 1975). The bronchiolitis obliterans of Swyer-James syndrome certainly affects bronchi at this level of arborisation (Macleod, 1954).

This is the third reported case of Swyer-James syndrome protecting the affected lung from pulmonary oedema, and the first in which the disease was confined to a lobe. Awareness of this entity is necessary to ensure correct diagnosis.

REFERENCES

BHASKAR, G., MURALIDHARA, R. & TSENG, T., 1980. Unilateral pulmonary oedema with Swyer-James syndrome. *Journal of the Kansas Medical Society*, *81*, 467–468.

CALENOFF, L., KRUGHLIK, G. D. & WOODRUFF, A., 1978. Unilateral pulmonary oedema. *Radiology*, *126*, 19–24.

COTTRELL, T. S., LEVINE, R., SENIOR, R. M., WEINER, J., SPIRO, D. & FISHMAN, A. P., 1967. Electron microscopic alterations at the alveolar level in pulmonary oedema. *Circulation Research*, *21*, 783.

HEITZMAN, E. R., 1976. *The Lung. Radiologic-Pathologic Correlations.* (Mosby, St Louis), pp. 11–254.

HURLEY, K. V. & JAGO, M. V., 1975. Pulmonary oedema in rats given dehydromoncrotanine: a topographic and electron-microscopic study. *Journal of Pathology*, *117*, 23.

MACLEOD, E. M., 1954. Abnormal transradiancy of one lung. *Thorax*, *9*, 147–153.

MACPHERSON, R. I., CUMMING, G. R. & CHERNICK, V., 1969. Unilateral hyperlucent lung; a complication of viral pneumonia. *Journal of the Canadian Association of Radiologists*, *20*, 225–231.

REID, L. & SIMON, G., 1962. Unilateral lung transradiancy. *Thorax*, *17*, 230–239.

SALEH, M., MILES, A. & LASSER, P., 1974. Unilateral pulmonary oedema in Swyer-James syndrome. *Chest*, *66*, 594–597.

SWYER, P. R. & JAMES, G. C. W., 1953. A case of unilateral pulmonary emphysema. *Thorax*, *8*, 133–136.

Congenital cystic adenomatoid malformation of the lung in a young adult

By J. R. Pulpeiro, M.D., *I. López, M.D., *T. Sotelo, M.D., J. C. Ruiz, M.D. and E. Garcia-Hidalgo, M.D.

Departments of Diagnostic Radiology and *Pathology, Hospital Primero de Octubre, Madrid, Spain

(Received September 1986 and in revised form February 1987)

Congenital cystic adenomatoid malformation (CCAM) of the lung is an infrequent lesion characterised by proliferation of bronchiole-like structures and cyst formation (Ostor & Fortune, 1978; Miller et al, 1980). The lesion usually causes severe respiratory distress early in the neonatal period. The presentation of CCAM after the first year of life is extremely rare (Madewell et al, 1975). This paper presents a case of CCAM of the lung in a 18-year-old girl.

CASE REPORT

A previously healthy 18-year-old girl was admitted to the hospital for elucidation of a cystic pulmonary lesion in the right upper lobe. Such a lesion was detected incidentally 1 year before and had remained unchanged despite 7 months of treatment with several antibiotics.

On admission, the patient had neither respiratory symptoms nor fever. The physical examination and routine laboratory tests were unremarkable. The tuberculin skin test was negative and culture and examination of the sputum for acid-fast bacilli also failed to demonstrate mycobacterium tuberculosis. The serological tests for hydatid disease were also negative. On chest radiographs a thin-walled lung cyst with an air-fluid level was observed in the anterior segment of the right upper lobe (Fig. 1). At surgery a cystic lesion in the right upper lobe, chronic inflammatory changes in the hilum and slight enlargement of regional lymph nodes were found. No abnormal arterial supply to the lesion was observed and right upper lobectomy was performed.

Examination of the gross specimen showed an irregular trabeculated cystic lesion, measuring 3.5 cm in the greatest diameter, surrounded by multiple small cysts (Fig. 2). Histologically, an abnormal proliferation of dilated bronchiole-like structures forming a network of interconnecting cysts was observed (Fig. 3). The cysts were lined by a pseudostratified epithelium with sparse goblet cells. The stroma was infiltrated by plasma cells and lymphocytes arranged in follicles. No striated muscle, bronchial glands or cartilage were found. The lumen of the cysts was filled with fibrinous material and *Aspergillus hyphae*. The final diagnosis was Stocker's Type I CCMA of the lung with fungus colonisation.

DISCUSSION

Congenital cystic adenomatoid malformation is the result of disturbed lung embryogenesis. No specific factors have been implicated in the pathogenesis and

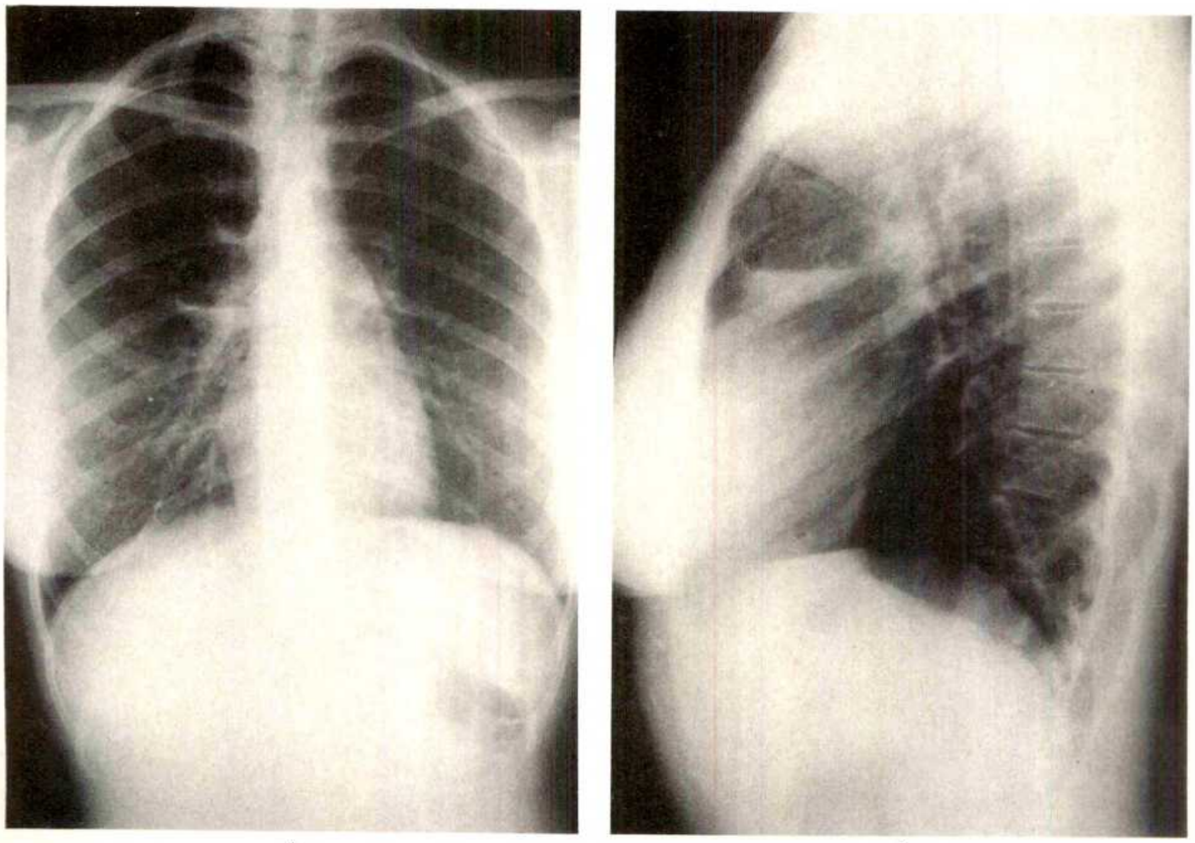


FIG. 1.

Chest radiographs showing an air–fluid level within a cystic lesion in the right upper lobe. (A) Postero-anterior and (B) lateral view.

CCAM has no sexual or racial predilection. The insult probably occurs between the fifth and sixth weeks, causing abnormal proliferation of terminal respiratory elements (Ostor & Fortune, 1978; Miller et al, 1980). The condition is unilateral in most cases and usually limited to a single lobe. Upper and lower lobes are equally affected, whereas middle-lobe involvement is unusual (Miller et al, 1980). Multilobar CCAM is not uncommon, but bilateral occurrence is extremely rare (Stocker et al, 1977).

Remarkable histological features of CCAM are replacement of normal lung parenchyma by proliferating bronchiole-like structures, macro- or microcysts lined by pseudostratified ciliated columnar epithelium or simple cuboidal epithelium, and absence of cartilage and bronchial glands. Inflammatory changes are not found in neonatal CCAM, but may be observed in late forms (Miller et al, 1980). Based on the size of the cysts, CCAM can be classified into three types: Type I shows single or multiple large cysts, over 2 cm in diameter; Type II lesions show multiple small cysts, less than 1 cm in diameter; and Type III or "solid" CCAM is composed of microcystic bronchiole-like structures (Stocker et al, 1977). Type I lesions are the most common and the only reported type in adults (Avitabile et al, 1984). Type II CCAM is frequently associated with other congenital anomalies mainly affecting the genito-urinary and gastrointestinal tract (Stocker et al, 1977). Vascular supply to CCAM is normal in most cases, although abnormal vascular connections have been occasionally reported. Such cases, however, are histologically indistinguishable from pulmonary sequestration (Avitabile et al, 1984).

Most cases of CCAM cause severe respiratory distress during the first week of life (Madewell et al, 1975). Less frequently the lesion is detected in childhood, associated with recurrent respiratory infection. The presentation of CCAM in adulthood is exceptional, the first two cases reported only recently (Avitabile et al, 1984; Hulnick et al, 1984).

The radiological findings of adult CCAM include single or multiple thin-walled cysts located in the lower lobes of the lung. Air-fluid levels within the cysts or even completely fluid-filled cysts simulating an intrapul-

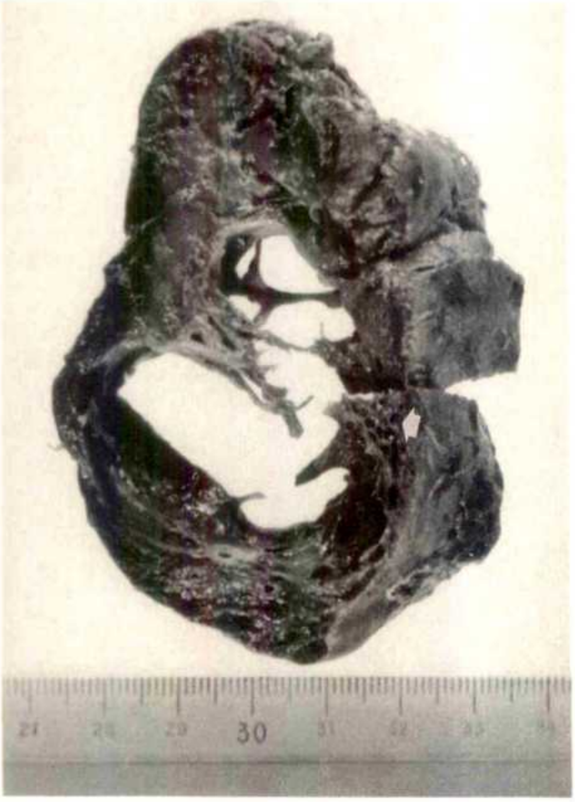


Fig. 2.

Surgical specimen showing a large, multiseptated central cavity surrounded by small cysts (arrow).

monary mass may be found (Hulnick et al, 1984). Except for the location in upper lobes, such findings were similar in our case.

Usually, CCAM is not considered as a cause of cystic lesions of the lung in adults. This case re-emphasises that, although unusual, CCAM of the lung may occur in adults and is not exclusive to the neonatal period. Thus CCAM of the lung should be considered when thin-walled cystic pulmonary lesions of uncertain origin are seen in the adult.

REFERENCES

Avitabile, A. M., Greco, M. A., Hulnick, D. H. & Feiner, H. D., 1984. Congenital cystic adenomatoid malformation of the lung in adults. *American Journal of Surgical Pathology*, *8*, 193–202.

Hulnick, D. H., Naidich, D. P., McCauley, D. I. Feiner, H. D., Avitabile, A. M., Greco, M. A. & Genieser, N. B., 1984. Late presentation of congenital cystic adenomatoid malformation of the lung. *Radiology*, *151*, 569–573.

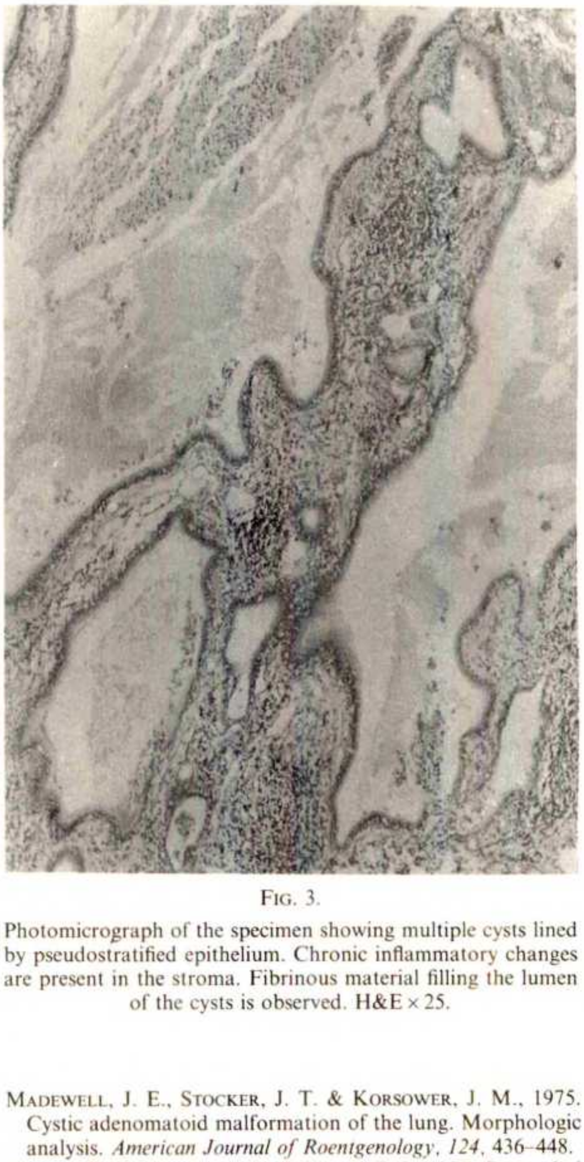


Fig. 3.

Photomicrograph of the specimen showing multiple cysts lined by pseudostratified epithelium. Chronic inflammatory changes are present in the stroma. Fibrinous material filling the lumen of the cysts is observed. H&E × 25.

Madewell, J. E., Stocker, J. T. & Korsower, J. M., 1975. Cystic adenomatoid malformation of the lung. Morphologic analysis. *American Journal of Roentgenology*, *124*, 436–448.

Miller, R. K., Sieber, W. K. & Yunis, E. J., 1980. Congenital adenomatoid malformation of the lung. A report of 17 cases and review of the literature. In *Pathology Annual* (Part 1). Ed. by S. C. Sommers & P. P. Rosen (Appleton Century Croft, New York), pp. 387–407.

Ostor, A. & Fortune, D. W., 1978. Congenital cystic adenomatoid malformation of the lung. *American Journal of Clinical Pathology*, *70*, 595–604.

Stocker, J. T., Madewell, J. E. & Drake, R. M., 1977. Congenital cystic adenomatoid malformation of the lung: classification and morphologic spectrum. *Human Pathology*, *8*, 155–171.

1987, *The British Journal of Radiology*, 60, 1131–1132

Case reports

Lymph-node calcification in Lennert's lymphoma

By M. P. Williams, F.R.C.R. and G. R. Cherryman, F.R.C.R.

CRC Radiology Research Group, Royal Marsden Hospital, Downs Road, Sutton, Surrey SM2 5PT

(*Received February 1987*)

Radiologists recognise that calcification may occur in the lymph nodes of patients previously treated for lymphoma (Brereton & Johnson, 1974; Bohlman et al, 1981). It is less commonly appreciated that calcification may be present in the lymph nodes of patients with malignant lymphoma prior to treatment. A case of Lennert's lymphoma with calcification seen in a mesenteric lymph node mass at presentation is described. We believe this to be the first report of this association.

CASE REPORT

A 66-year-old, previously well woman presented with a 2-month history of loss of appetite, nausea, tiredness and weight loss. On examination she was found to have a mobile mass in the left side of the abdomen but no other abnormal physical findings. Investigations at this time showed hypercalcaemia with a serum calcium level of 3.41 mmol/l.

At laparotomy, a tumour involving the full thickness of the terminal ileum was found together with a fixed mass of nodes in the right iliac fossa and a left-sided mesenteric mass. The tumour of the terminal ileum was resected and biopsies taken of the liver and nodal masses. Histologically, all three sites showed infiltration by a malignant lymphoid tumour comprising abnormal lymphocytes with positive T-cell markers, abundant histiocytes and a few cells indistinguishable from Reed-Sternberg cells. These features are compatible with a diagnosis of Lennert's lymphoma.

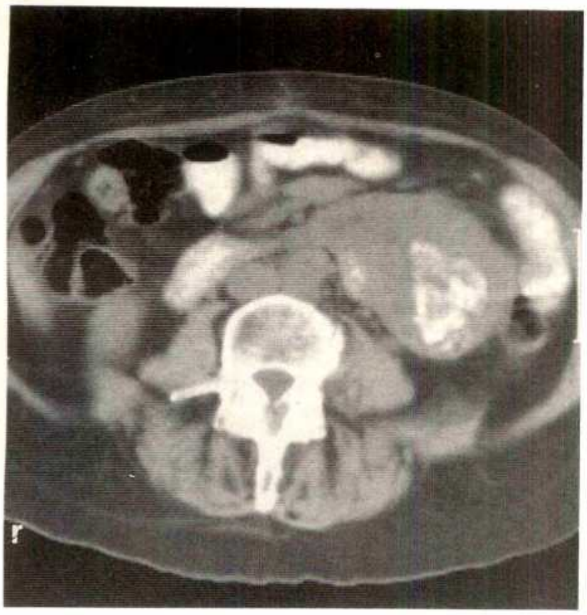


FIG. 1.

This CT section through the lower abdomen shows a large mesenteric mass with central calcification. Note that the small-bowel loops are opacified by oral contrast medium. (Window width 372, window level 14.)

She was subsequently referred to the Royal Marsden Hospital and computed tomography (CT) was undertaken as part of a lymphoma staging protocol. The CT scan showed no evidence of pulmonary or mediastinal involvement but demonstrated extensive retroperitoneal lymphadenopathy extending in continuity from the retrocrural region down the para-aortic lymph node chains into a large mass of nodes on the right pelvic side-wall. A separate mesenteric mass measuring approximately 10 cm × 8 cm in diameter was also demonstrated and contained a central area of calcification (Fig. 1).

The patient was intially treated with a combination of bleomycin, vincristine, mitozantrone and cyclophosphamide. After eight courses of chemotherapy a repeat CT scan showed considerable resolution of her intra-abdominal disease with decrease in size of the para-aortic and pelvic nodes, and reduction in size of the mesenteric mass. The central area of calcification within the mesenteric mass remained unchanged.

After the ninth course of chemotherapy the patient developed a drug-induced pneumonitis from which she died. A post-mortem examination was not performed.

DISCUSSION

The majority of reports of lymph-node calcification following therapy for lymphoma concern Hodgkin's disease rather than non-Hodgkin's lymphoma. Indeed, a recent review of the literature revealed only five reported cases of lymph node calcification occurring after therapy for non-Hodgkin's lymphoma (Strijk, 1985). The calcification appeared in treated nodes between 5 months and 19 years post-treatment, with a mean of 5 years. The calcification was dystrophic in nature, probably occurring in areas where tumour necrosis had been followed by healing and fibrosis. Calcification in untreated lymphoma is extremely rare, with only three reports in the English literature (Massachusetts General Hospital, 1956; Korek-Amorosa et al, 1974; Wycoco & Raval, 1983) describing calcification occurring in Hodgkin's disease, and a further report in the German literature (Fischer et al, 1975).

Hypercalcaemia in lymphoma is usually thought to indicate bone-marrow involvement. However, in our patient a bone-marrow aspirate and trephine did not show evidence of lymphoma. The occurrence of a high serum calcium level in malignancy is not uncommon but is rarely associated with lymph-node calcification (Moses & Spencer, 1963). In our case we postulate that lymph-node calcification occurred because of spontaneous tumour necrosis in the presence of a high serum level of calcium. We believe this to be the first reported case of lymph-node calcification occurring spontaneously in the so-called Lennert's lymphoma.

Lennert's lymphoma was first described by Lennert and Mestdagh (1968) and was originally thought to be a variety of Hodgkin's disease with a high content of epithelioid histiocytes and few Reed-Sternberg cells. Subsequently it has been recognised that Lennert's lymphoma is in fact a distinct non-Hodgkin's lymphoma with a florid epithelioid histiocytic reaction (Burke & Butler, 1976; Kim et al, 1980). In the study by Kim et al (1980) the average age of onset of the disease was 64 years, with 88% of patients presenting with Stage III or Stage IV disease. The prognosis of the disease is poor, having a mean survival time of 12 months from diagnosis.

In our patient a histological diagnosis was made at surgery prior to formal staging. It is important, however, that radiologists recognise that the presence of calcification within a lymph-node mass does not exclude the diagnosis of lymphoma. Previous reports have suggested this to be an extremely rare feature of Hodgkin's disease. We have now recorded such an occurrence in malignant non-Hodgkin's Lennert's lymphoma.

REFERENCES

Bohlman, M. E., Lichtenfeld, J. L. & Goldman, S. M., 1981. Lymph node calcification secondary to chemotherapy for histiocytic lymphoma. *Diagnostic Imaging*, *50*, 259–262.

Brereton, H. D. & Johnson, R. E., 1974. Calcification in mediastinal lymph nodes after radiation therapy of Hodgkin's disease. *Radiology*, *112*, 705–707.

Burke, J. S. & Butler, J. J., 1976. Malignant lymphoma with a high content of epithelioid histiocytes (Lennert's lymphoma). *American Journal of Clinical Pathology*, *66*, 1–9.

Fischer, J. Th., Jungblut, R. M. & Knieriem, H. J., 1975. Primar verkalkte Lymphogranulomatose. *Deutsche Medizinische Wochenschrift*, *100*, 185–187.

Kim, H., Nathwani, B. N. & Rappaport, H., 1980. So called "Lennert's" lymphoma: is it a clinicopathologic entity? *Cancer*, *45*, 1379–1399.

Korek-Amorosa, J., Scheinman, H. Z., Clemett, A. R., Amorosa, L. F. & McKenna, P., 1974. Hypercalcaemia and extensive lymph node calcification in a patient with Hodgkin's disease prior to therapy. *British Journal of Radiology*, *47*, 905–907.

Lennert, K. & Mestdagh, J., 1968. Lymphogranulomatosen mit konstant hohem epitheloid-zellgehalt. *Virchows Archiv A: Pathological Anatomy and Histology*, *344*, 1–20.

Massachusetts General Hospital, 1956. Case Record No. 42242. *New England Journal of Medicine*, *254*, 1139–1141.

Moses, A. M. & Spencer, H., 1963. Hypercalcaemia in patients with malignant lymphoma. *Annals of Internal Medicine*, *59*, 531–536.

Struk, S. P., 1985. Lymph node calcification in malignant lymphoma. Presentation of nine cases and a review of the literature. *Acta Radiologica Diagnosis*, *26*, 427–431.

Wycoco, D. & Raval, B., 1983. An unusual presentation of mediastinal Hodgkin's lymphoma on computed tomography. *Computed Tomography*, *7*, 187–188.

Submucosal gastric haematoma: a case report and review of the literature

By Simon Elliott, F.R.C.R and *James Bruce, F.R.C.S.

Departments of Radiology and *Surgery, Queen's Medical Centre, Nottingham

(Received February 1987)

Submucosal or intramural haematoma of the stomach is a well recognised complication of patients with clotting disorders, particularly haemophiliacs, and also as a result of direct trauma during fibreoptic gastroscopy. However, there do not appear to be any recorded cases of submucosal haematoma following the inadvertent ingestion of a foreign body.

Case Report

A 73-year-old man presented, having eaten fish some hours previously which at the time caused some retrosternal discomfort. Three to four hours later he developed severe retrosternal chest pains which were exacerbated by swallowing. There was no nausea or vomiting. Examination was unremarkable apart from minimal epigastric tenderness and there was no evidence of circulatory shock. A clinical diagnosis of oesophageal perforation was considered. Plain radiographs of the chest showed no evidence of mediastinal emphysema or pleural effusions but abdominal radiographs showed a smooth, rounded filling defect at the cardia of the stomach (Fig. 1).

---

*Present address: The Children's Hospital of Buffalo, New York.

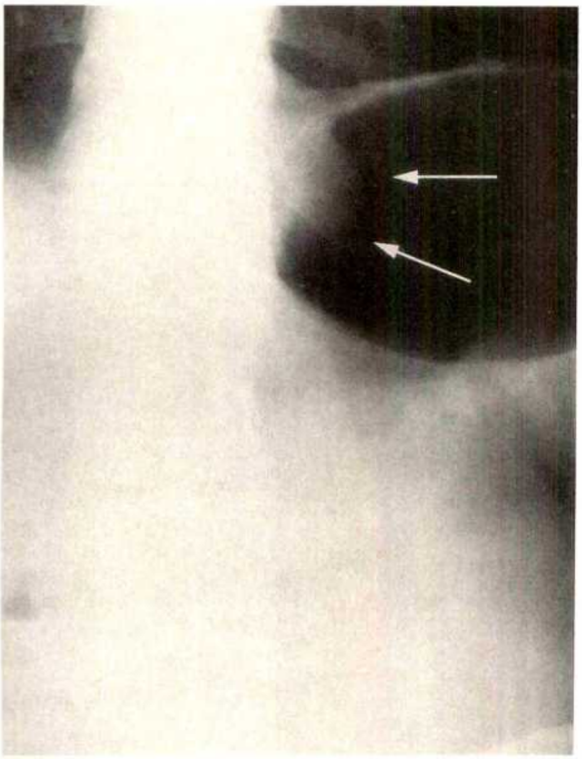


FIG. 1.

Plain radiograph demonstrating a filling defect at the gastric cardia (arrows).

Barium studies confirmed the presence of the filling defect, measuring 5 cm in diameter (Fig. 2). This appeared to be a submucosal mass and a constant "pit" of barium at its centre prompted a radiological diagnosis of an ulcerated leiomyoma. Interestingly the patient experienced excruciating pain whenever the barium came in contact with the lesion. The oesophagus was otherwise normal.

At endoscopy next day, the mucosa was shown to be elevated by a tense haematoma. The mucosa had a small tear corresponding to the constant "pit" of barium and bled readily on contact with the endoscope.

A diagnosis was made of a submucosal haematoma and the patient was treated symptomatically, initially restricted to fluids, and was discharged 4 days later. A clotting screen was normal.

Follow-up endoscopy three weeks later showed complete healing with a normal oesophagus and stomach.

DISCUSSION

Spontaneous intramural or submucosal gastric haematomas, although rare, are relatively well documented with 12 cases in the literature. There is also a single case report in a horse: this appeared to be chronic in nature and measured 80 cm in diameter, containing

TABLE I

REPORTED CASES OF INTRAMURAL GASTRIC HAEMATOMA

Case	Age (years)	Sex	Position of haematoma	Underlying disease	Direct cause	Treatment
1	8	M	Posterior wall	Haemophilia A	Unknown	Cryoprecipitate
2	27	F	Fundus	Alcoholic?	Perforated gastric ulcer	Laparotomy
3	48	M	Fundus	—	Trauma from compressed air drill	Laparotomy
4	41	M	Antrum	von Willebrand's disease	Duodenal ulcer	Laparotomy
5	8	M	Greater curvature	Haemophilia A	Unknown	Cryoprecipitate
6	22	M	Greater curvature	Haemophilia A	Unknown	Cryoprecipitate
7	72	M	Cardia	—	Mallory-Weiss syndrome	Laparotomy
8	24	F	Cardia	Systemic lupus erythematosus (SLE) Warfarin	Unknown	None
9	84	F	Lesser curve	Myelofibrosis	Unknown	Transfusion
10	41	F	Posterior wall	SLE	Pancreatitis	Transfusion
11	10	M	Greater curve (gastric outlet obstruction)	Haemophilia A	Unknown	Cryoprecipitate
12	23	M	Body	Haemophilia A	Unknown	Cryoprecipitate
13	73	M	Cardia	—	Ingestion of foreign body	Conservative

Cases 1–8 (Darward et al, 1979); Case 9 (Melato et al, 1980); Case 10 (Lloyd & Johnson, 1980); Case 11 (Gordon et al, 1981); Case 12 (Griffin & Chopra, 1985); Case 13, present case.

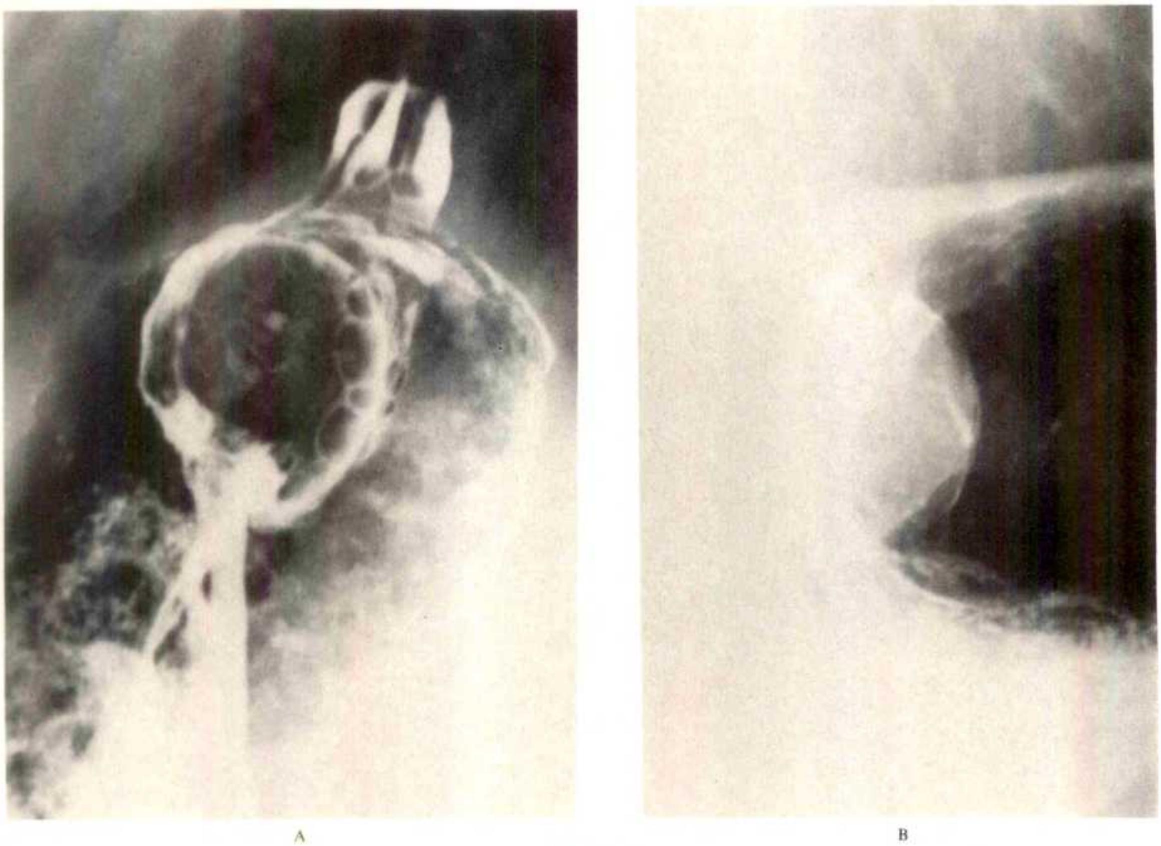


FIG. 2.

(A), (B) Barium studies demonstrating the submucosal haematoma and small mucosal tear (central fleck of barium).

some 100 l of pink fluid! Its aetiology was unknown (Brown et al, 1981).

A review in 1979 detailed eight cases (Darward et al, 1979). Table I shows a revised summary of reported cases including our case. Nine, possibly 10 (Case 2), had an underlying coagulation defect. In Case 12, the haematoma was the presenting complaint in a previously undiagnosed haemophiliac. In seven of the 13 cases no actual cause for the formation of the haematoma was identified. In the remaining six, the cause varied from acute gastric or duodenal ulceration to pancreatitis.

Intestinal intramural haematomas are well recognised as a result of blunt trauma. However, in a review of 109 cases, 102 occurred in the duodenum, three in the small bowel and four in the colon, with no recorded cases within the stomach (Hughes et al, 1977). Gastric haematomas are, however, recognised as a result of direct trauma during fibreoptic gastroscopy with the commonest site being just distal to the cardia. This is said to be due to the angulation at this site produced by the retroperitoneal structures (Meyers & Ghahremani, 1975). The development of a haematoma following the inadvertent ingestion of a foreign body, while representing a form of local trauma, has not previously been reported. As in the case of traumatic gastroscopy, this case of haematoma was just distal to the cardia. Intramural haematoma and dissection of the oesophagus secondary to ingestion of a foreign body is, however, well recognised. In a recent review it was commented that the condition was more common in edentulous patients (Lamont et al, 1985); our patient was also edentulous.

The general mode of presentation of spontaneous gastric haematoma was of several days of upper abdominal discomfort, nausea and vomiting. Melaena occurred in Case 4. Severe epigastric pain occurred in two cases, including our own, and a palpable mass was present in three cases. Resolution of the haematoma can be expected in 3–6 weeks.

Misdiagnosis of the haematoma can be disastrous. Case 2 underwent laparotomy and a clinical diagnosis of a lymphosarcoma was made with removal of the stomach, spleen, tail of the pancreas and left hemidiaphragm. The commonest misdiagnosis was, as in our case, of a leiomyoma or leiomyosarcoma.

1987, *The British Journal of Radiology*, *60*, 1135–1136 NOVEMBER 1987

Endoscopy should provide the definitive diagnosis. Ultrasound has been utilised in monitoring the resolution of haematoma (Gordon et al, 1981), however, this only seems practical with large lesions.

Although gastric haematomas are relatively uncommon, their recognition is important; surgery is obviously to be avoided if at all possible, particularly in haemophiliacs or other coagulopathies. Those cases occurring in haemophiliacs did uniformly well with correction of the coagulopathy despite some haematomas occupying the entire gastric lumen.

ACKNOWLEDGMENTS

We would like to thank Mr C. A. S. Pegg, Consultant Surgeon at Nottingham, for permission to report this case, and Miss P. Gamble for typing the manuscript.

REFERENCES

BROWN, C. M., COLLIER, M. A. & JACOBSEN, K. A., 1981. Gastric haematoma in a horse. *Modern Veterinary Practice*, *82*, 617–618.

DARWARD, Q. J., COHEN, M. M. & NAIMAN, S. C., 1979. Intramural haematoma of the gastric cardia. *American Journal of Gastroenterology*, *71*, 301–305.

GORDON, R. A., D'AVIGNON, M. B., STORCH, A. E. & EVSTER, M. E. 1981. Intramural gastric haematoma in a haemophiliac with an inhibitor. *Paediatrics*, *67*, 417–419.

GRIFFIN, P. H. & CHOPRA, S., 1985. Spontaneous intramural gastric haematoma, a unique presentation for haemophilia. *American Journal of Gastroenterology*, *80*, 430–433.

HUGHES, C. E., CONN, J. & SHERMAN, J. O., 1977. Intramural haematoma of the gastrointestinal tract. *American Journal of Surgery*, *133*, 276–279.

LAMONT, G., ELLIOTT, S. & MORRIS, D. L., 1985. Spontaneous intramural oesophageal dissection. *Thorax*, *40*, 558–559.

LLOYD, T. V. & JOHNSON, J. C., 1980. Intramural gastric haematoma secondary to splenic rupture. *Southern Medical Journal*, *73*, 1675–1676.

MELATO, M., FALCONIERI, G., MANCONI, R. & BUCCONI S., 1980. Intramural gastric haematoma and haemoperitoneum occurring in a patient affected by idiopathic myelofibrosis. (Letter.) *Human Pathology*, *11*, 301–302.

MEYERS, M. A. & GHAHREMANI, G. G., 1975. Complications of fibreoptic endoscopy. *Radiology*, *115*, 293–300.

Detection of mesenteric involvement in sarcoidosis using computed tomography

By *Faysal A. Saksouk, M.D. and †Maurice C. Haddad, M.D.

Department of Radiology, American University of Beirut Medical Center, Beirut, Lebanon

(*Received July 1986 and in revised form March 1987*)

Abdominal lymph-node involvement by sarcoidosis may be more common than is generally recognised (Miller et al, 1981). Recent reports have stressed the frequency of the detection of retroperitoneal adenopathy in sarcoidosis by computed tomography (CT) (Miller et al, 1981; Meranze et al, 1985), but very little attention has been given in the literature to the possibility of similar involvement of the mesenteric lymph nodes. We present a proven case of sarcoidosis with mesenteric and retroperitoneal manifestations simulating non-Hodgkin's lymphoma.

CASE REPORT

A 61-year-old white man with recently discovered renal failure was found by ultrasound to have left hydronephrosis. A retrograde pyelogram was performed and showed an irregular filling defect in the distal left ureter which raised the possibility of tumour. The chest radiographs obtained at this time showed hilar enlargement and ill-defined nodular lung opacities, interpreted as being due to metastasis.

On admission to our hospital a CT scan of the abdomen proved the ureteric filling defect to represent a calculus. However, the examination also revealed the presence of a bulky mesenteric soft-tissue mass, as well as discretely enlarged retroperitoneal lymph nodes (Fig. 1). These latter findings suggested the possibility of non-Hodgkin's lymphoma. No palpable peripheral adenopathy was found on physical examination. The serum creatinine was 3.4 mg.%, uric acid 10.4 mg.% and calcium 12.4 mg.%. The urine contained numerous red blood cells.

Exploratory laparotomy confirmed the presence of a 7 cm × 6 cm mesenteric mass in the mid-abdomen, encasing the main mesenteric vessels distal to the root of the mesentery. Left ureterolithotomy was performed together with biopsy of the mesenteric mass and the right iliac bone. Pathological examination of the mass showed confluent fibrosis with non-caseating granulomas characteristic of sarcoidosis. Non-caseating granulomas were also found in the iliac-bone biopsy. Acid-fast and fungal special staining were negative.

Chest radiographs and abdominal CT performed after 3 months of steroid therapy showed marked clearing of the lungs, decrease of the hilar enlargement, and regression of the abdominal adenopathy.

Correspondence and reprint requests to F. A. Saksouk at address below.

*Present address: Department of Radiology, Duke University Medical Center, PO Box 3808, Durham, North Carolina 27710, USA.

†Present address: Department of Radiology, University Hospital of Wales, Heath Park, Cardiff CF4 4XN.

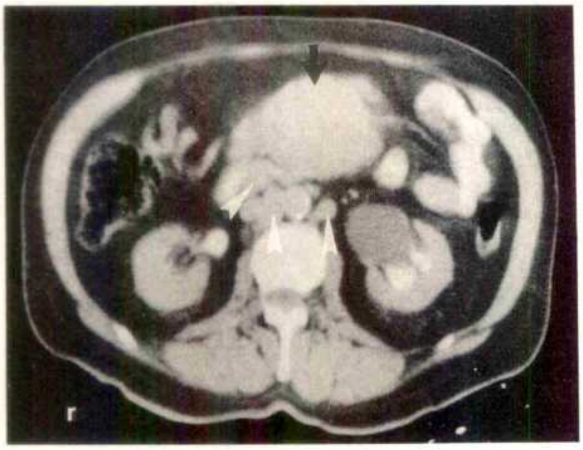


FIG. 1.

A CT scan with intravenous and oral contrast medium at the level of the mid-kidneys shows a large, well demarcated soft-tissue mass (arrow) in the mesentery and slightly enlarged discrete lymph nodes (arrowheads) in the retroperitoneum. The central portions of the mesenteric vessels are engulfed and obscured by the mass. The left hydronephrosis is due to a distal ureteric calculus.

DISCUSSION

Sarcoidosis is a systemic, non-caseating granulomatous disease most frequently involving the lungs, lymph nodes and spleen (Sprague et al, 1984). The lungs and intrathoracic lymph nodes are involved in more than 90% of cases (DeRemee, 1984), the diagnosis usually being first suggested by the characteristic and well known radiographic appearance of the chest produced by enlargement of the right paratracheal and bilateral hilar lymph nodes (Miller et al, 1981; DeRemee, 1984; Meranze et al, 1985). The retroperitoneal lymph nodes may be involved in up to 75% of chronic cases but this feature has been highlighted only recently in the literature dealing with the newer sectional imaging modalities (Miller et al, 1981; Meranze et al, 1985). Involvement of the mesenteric lymph nodes in sarcoidosis has not received much attention, possibly because they are less commonly involved than the retroperitoneal nodes. While there are several pathology reports of isolated sarcoid granulomas found in mesenteric lymph nodes (Sprague et al, 1984), this was not the experience of Iwai and Oka who, although finding intra-abdominal lymph-node involvement in nine of 10 autopsy cases of sarcoidosis, found no mesenteric nodal involvement (Miller et al, 1981). The incidence of detectable mesenteric adenopathy on CT examination has not been much different. Miller et al (1981) reported a patient with sarcoidosis and minimal pulmonary findings in whom CT showed hepatosplenomegaly and extensive retroperitoneal adenopathy but no mesenteric adenopathy. Meranze et al (1985) reported three additional cases of sarcoidosis in which retroperitoneal adenopathy was discovered by CT, but only one showed evidence of mesenteric disease with a few slightly enlarged, discrete mesenteric nodes. We add yet another case of sarcoidosis with retroperitoneal and mesenteric involvement detected by CT but with the difference that the mesenteric abnormality is the major finding and in the form of a single bulky mesenteric mass.

Single bulky and well demarcated soft-tissue masses found in the mesentery may be due to primary mesenteric desmoid tumours (Baron & Lee, 1981) but are more frequently due to lymphoma or metastatic disease, where they are thought to represent conglomeration of lymph nodes (Levitt et al, 1978). However, coexistence of such single large mesenteric masses with retroperitoneal adenopathy on CT is most commonly a manifestation of non-Hodgkin's lymphoma (Bernardino et al, 1979). Our case shows that sarcoidosis can have similar abdominal CT manifestations and, where clinically appropriate, should be included in the differential diagnosis.

ACKOWLEDGMENT

We would like to thank Ms Lorraine Williams and Ms Wadad Jaber for their assistance in the preparation of this manuscript.

REFERENCES

BARON, R. L. & LEE, J. K. T., 1981. Mesenteric desmoid tumors: sonographic and computed tomographic appearance. *Radiology*, *140*, 777–779.

BERNARDINO, M. E., JING, B. S. & WALLACE, S., 1979. Computed tomography diagnosis of mesenteric masses. *American Journal of Roentgenology*, *132*, 33–36.

DEREMEE, R. A., 1984. Sarcoidosis, current perspectives on diagnosis and treatment. *Post-graduate Medicine*, *76*, 167–172.

LEVITT, R. G., SAGEL, S. S. & STANLEY, R. J., 1978. Detection of neoplastic involvement of the mesentery and omentum by computed tomography. *American Journal of Roentgenology*, *131*, 835–838.

MERANZE, S., COLEMAN, B., ARGER, P., MINTZ, M. & MARKOWITZ, L., 1985. Retroperitoneal manifestations of sarcoidosis on computed tomography. *Journal of Computer Assisted Tomography*, *9*, 50–52.

MILLER, L. K., ROCHESTER, D. & MILLER, J. W., 1981. Extensive abdominal lymphadenopathy in sarcoidosis. *American Journal of Gastroenterology*, *75*, 367–369.

SPRAGUE, R., HARPER, P., MCCLAIN, S., TRAINER, T. & BEEKEN, W., 1984. Disseminated gastrointestinal sarcoidosis. Case report and review of the literature. *Gastroenterology*, *87*, 421–425.

1987, *The British Journal of Radiology*, 60, 1137–1138 NOVEMBER 1987

Case reports

The radiological findings in syphilitic proctitis

By Thanit Singcharoen, M.D. and Ong-Ard Praisontarangkul, M.D.

Department of Radiology and Medicine, Faculty of Medicine, Chiang Mai University, Chiang Mai 50000, Thailand

(*Received March 1987*)

Rectal syphilis is being recognised more frequently because of the increased incidence of syphilis among homosexual men and many reports have stated that this condition may be more common than is generally appreciated. Previous reports were related mainly to proctoscopic and histopathological findings (Marino, 1964; Smith, 1965; Gluckman et al, 1974; Nazemi et al, 1975; Akdamar et al, 1977; Quinn et al, 1982); the purpose of this paper is to describe the radiographic findings on barium enema examination in a case of rectal syphilis.

CASE REPORT

A 39-year-old homosexual man was referred for diagnosis and management of mucous, bloody stools during the previous month. Physical examination was unremarkable except for multiple irregularly shaped ulcers around the anus. Rectal examination revealed an indurated, nodular mucosa around the rectal lumen which was tender on palpation. Barium enema showed the irregular mucosa and narrowing of the lumen of the rectum with widening of the pre-sacral space (Fig. 1). Flexible proctosigmoidoscopy revealed inflamed hypertrophic mucosa with ulcerations mimicking tumour around the rectal wall extending up to 12 cm from the anal verge.

Dark-ground microscopic examination demonstrated many motile spirochaetes from both perianal and rectal ulcers. The Venereal Diseases Reference laboratory (VDRL) test was positive at a titre of 1 : 16. Biopsy showed submucosal infiltration with plasma cells and perivascular inflammation compatible with syphilis. The diagnosis of rectal syphilis with perianal chancres was made and a course of benzathine penicillin was given. The rectal symptoms, mucosal lesions and perianal ulcers gradually improved. Barium enema 6 months later showed almost normal appearance of the rectum and presacral space (Fig. 2).

DISCUSSION

Primary syphilis of the rectum or rectal chancres result from rectal intercourse with an infected person. The incubation period is 2–8 weeks. Grossly, the lesions of rectal syphilis usually appear as necrotic and indurated ulcers commonly located on the anterior rectal wall. Cases with heaped-up granulation tissue mimicking polyps or even tumour masses have been reported (Drusin et al, 1977; Quinn et al, 1982; Faris et al, 1983). Some individuals have undergone surgical resection of these lesions prior to the diagnosis of syphilis by serological tests and histology of the resected tissue (Drusin et al, 1976).

Histologically, the rectal lesions show mixed plasma cell and lymphocytic and histiocytic vasculitis with reactive submucosal granulation tissue. On some occasions the presence of pleomorphic cells and atypical lymphocytes misled the pathologists to the diagnosis of malignant lymphoma, especially in cases with lymphadenopathy (Faris et al, 1983). The useful laboratory tests are dark-ground microscopic examination for *Treponema pallidum* and serological tests:—

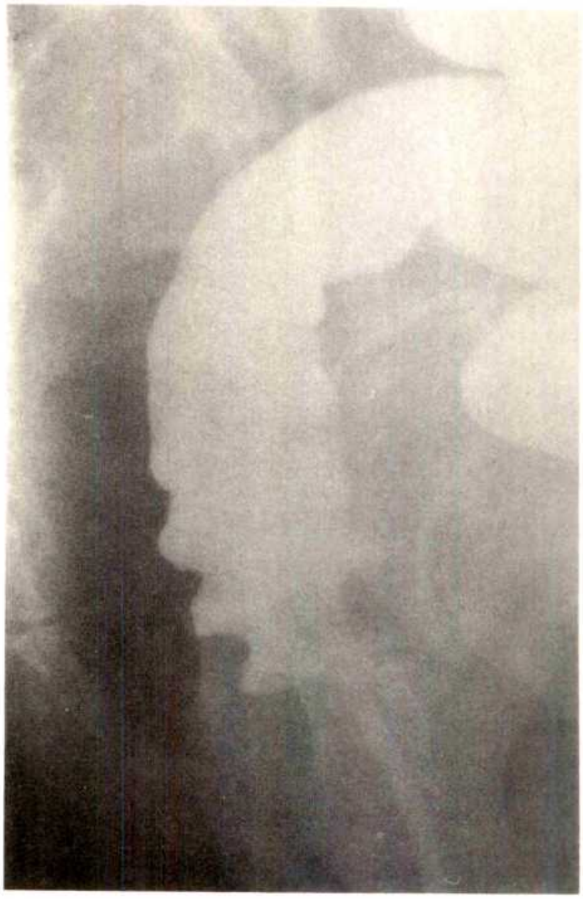


FIG. 1.

Barium enema: lateral view of the rectum shows induration and irregularity of the rectal mucosa, which involved a relatively long segment circumferentially. Slight widening of the pre-sacral space is noted.

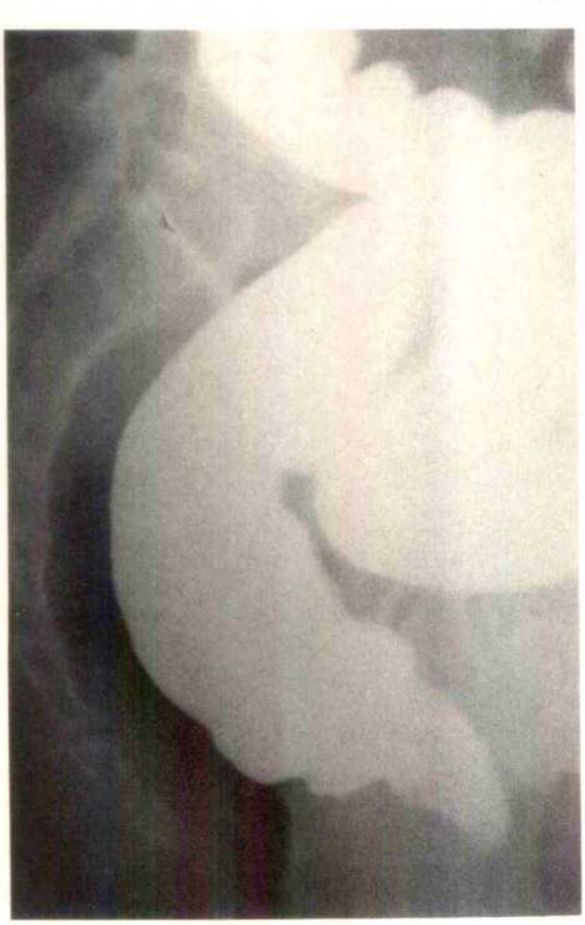


FIG. 2.

Follow-up barium enema shows almost normal appearance of the rectum and presacral space. Only minimal irregularity of the lower rectum is observed.

VDRL and fluorescent treponemal antibody-absorption tests.

To our knowledge the radiological findings of rectal syphilis have not been previously described. In this case barium enema examination demonstrated mucosal nodularity and a narrow rectal lumen compatible with the inflamed hypertrophic mucosa seen on endoscopy. Widening of the presacral space could be due to extensive submucosal or perirectal inflammation. The clinical and radiological findings in this patient indicated an inflammatory proctitis rather than neoplastic disease. Lymphogranuloma venereum, Crohn's disease, ulcerative proctitis, amoebiasis, tuberculosis or gonorrheal proctitis, may all produce similar appearances and must be considered in the differential diagnosis (Reeder & Palmer, 1981; Thoeni & Margulis, 1983). However, the history of rectal intercourse should have suggested a venereal infection.

Syphilis has been termed the great imitator and rectal syphilis is no exception. Clinical symptoms, gross appearance, histopathological and radiographic findings can be confusing. The diagnosis depends on maintaining a high index of suspicion. Rectal syphilis should be considered in the radiological diagnosis of the rectal lesions, especially in patients who have had rectal intercourse or who are found to have perianal ulcers.

REFERENCES

AKDAMAR, K., MARTIN, J. R. & ICHINOSE, H., 1977. Syphilitic proctitis. *Digestive Diseases, 22,* 701–704.

DRUSIN, L. M., HOMAN, W. P. & DINEEN, P., 1976. The role of surgery in primary syphilis of the anus. *Annals of Surgery, 184,* 65–67.

DRUSIN, L. M., SINGER, C., VALENTI, A. J. & ARMSTRONG, D., 1977. Infectious syphilis mimicking neoplastic disease. *Archives of Internal Medicine, 137,* 156–160.

FARIS, M. R., PERRY, J. J., WESTERMEIER, T. G. & REDMOND, J., 1983. Rectal syphilis mimicking histiocytic lymphoma. *American Journal of Clinical Pathology, 80,* 719–721.

GLUCKMAN, J. B., KLEINMAN, M. S. & MAY, A. G., 1974. Primary syphilis of rectum. *New York State Journal of Medicine, 74,* 2210–2211.

MARINO, A. W. M., 1964. Proctologic lesions observed in male homosexuals. *Diseases of the Colon and Rectum, 7,* 121–128.

NAZEMI, M. M., MUSHER, D. M., SCHELL, R. F. & MILO, S., 1975. Syphilitic proctitis in a homosexual. *Journal of the American Medical Association, 231,* 389.

QUINN, T. C., LUKEHART, S. A., GOODELL, S., MKRTICHIAN, E., SCHUFFLER, M. D. & HOLMES, K. K., 1982. Rectal mass caused by treponema pallidum: confirmed by immunofluorescent staining. *Gastroenterology, 82,* 135–139.

REEDER, M. M. & PALMER, P. E. S., 1981. Lymphogranuloma venereum. In *The Radiology of Tropical Disease.* (Williams & Wilkins, Baltimore), pp. 541–549.

SMITH, D., 1965. Infectious syphilis of the rectum. *Diseases of the Colon and Rectum, 8,* 57–58.

THOENI, R. F. & MARGULIS, A. R., 1983. Inflammatory diseases of the colon. In *Alimentary Tract Radiology.* Ed. by A. R. Margulis & H. J. Burhenne (C.V. Mosby, St Louis), pp. 1113–1159.

1987, *The British Journal of Radiology*, 60, 1139–1140 NOVEMBER 1987

Case of the month

An unusual inguinal swelling

By *O. Constant, M.B., M.R.C.P., F.R.C.R. and †R. A. Mitchell, M.B., B.Ch., F.R.C.R.

Departments of Radiology, *The Royal Marsden Hospital, Fulham Road, London SW3 6JJ and †Northwick Park Hospital, Harrow, Middlesex HA1 3UJ

(Received March 1987)

A 65-year-old woman presented to her general practitioner with a large, pulsatile, cystic swelling in the anterior aspect of her right groin, which was intermittently painful. It interfered with walking and was increasing in size. A femoral artery aneurysm was diagnosed and the patient was referred to a vascular surgeon. Nine years previously, she had developed late-onset polymyositis, treated with prednisolone for 5 years. No associated neoplasm was discovered, and symptoms did not reappear after cessation of steroid therapy. Ultrasound scan of the right groin showed a 2.5 cm × 5.0 cm cystic structure judged to be in continuity with the femoral artery. A diagnosis of femoral artery aneurysm was made. Intravenous digital subtraction angiography showed displacement medially of the common femoral artery but no abnormal circulation or accumulation of contrast medium in the mass.

Computed tomography (CT) (Fig. 1) showed the mass to be of lower density than muscle and to extend from the symphysis pubis to behind the rectus femoris. Plain radiography was unhelpful. Aspiration of the mass yielded clear fluid which grew no bacteria and did not contain neoplastic cells. The fluid reaccumulated after some weeks.

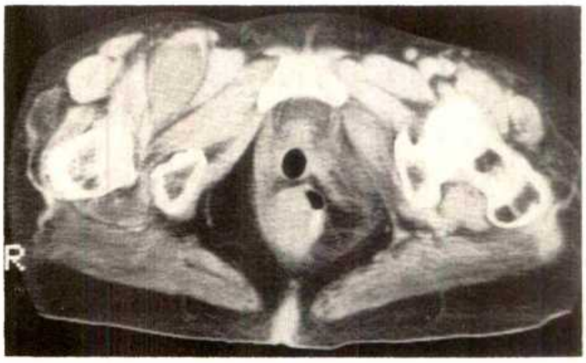
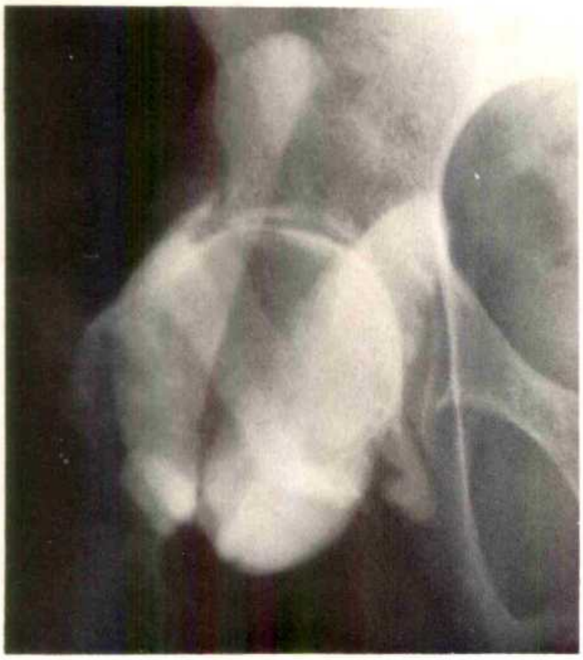


FIG. 1.

A CT scan showing a soft-tissue mass (mean attenuation 14 HU) lying anterior to the right hip joint, between the iliopsoas, pectineus and obturator externus muscles.

What are the possible diagnoses and how would you proceed?

All correspondence to: Dr O. Constant.



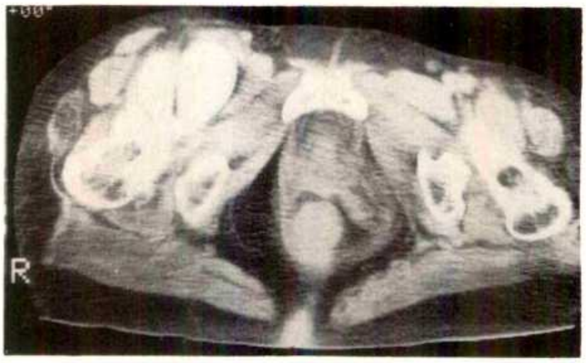


FIG. 2.

(A) Right hip arthrogram. Single-contrast study of the right hip showing contrast within the joint space, with extension into the iliopsoas bursa. (B) Computed tomographic arthrogram, right hip. Contrast medium is seen outlining the hip joint. The contrast medium-filled structure anterior to the joint space is the iliopsoas bursa. Communication with the hip joint was demonstrated by the filling with contrast.

At this stage the possibility of an iliopsoas bursa communicating with the hip joint was considered. A hip arthrogram followed by CT confirmed the passage of contrast medium into the iliopsoas bursa from the hip-joint injection (Fig. 2).

DISCUSSION

Enlargement of the iliopsoas bursa has been described in association with conditions causing synovitis. It may present as a pelvic mass (Janus & Hermann, 1982) or as an inguinal swelling.

The iliopsoas bursa is the largest bursa in the body and is present in 98% of adults. It lies behind the iliopsoas muscle and in front of the anterior aspect of the hip joint. It communicates with the hip joint in 15% of cases (Chandler, 1934). The incidence of this communication is significantly increased in those with arthritis of the hip (Melamed et al, 1967). Extension of hip disease into the bursa has been described in rheumatoid arthritis, osteoarthritis, and pigmented villonodular synovitis, and has caused diagnostic confusion. Bursal enlargement has been demonstrated by arthrography (Carrera et al, 1980), CT and ultrasound. Enlargement of the iliopsoas bursa presenting as a pelvic mass on ultrasound has been described in a patient with longstanding rheumatoid arthritis. In all the previously described cases, the underlying cause has been either rheumatoid arthritis or osteoarthritis, with or without previous hip surgery.

In our case, there was no previous history of joint disease or hip surgery, and the bursa was elegantly demonstrated by the most convincing method available—a CT study following hip arthrography. It illustrates the diagnostic delay that may occur if it is not included in the differential diagnosis of pulsatile groin masses and stresses the fact that it may occur in the absence of any of the previously documented predisposing causes.

REFERENCES

CARRERA, G. F., PAPADAKES, N. & IMRAY, T. J., 1980. Retropsoas extension of ruptured hip capsule: arthrographic demonstration. *American Journal of Roentgenology*, *135*, 1293–1294.

CHANDLER, S. B., 1934. The iliopsoas bursa in man. *Anatomical Record*, *50*, 235–240.

JANUS, C. & HERMANN, G., 1982. Enlargement of the iliopsoas bursa: unusual cause of cystic mass on pelvic sonogram. *Journal of Clinical Ultrasound*, *10*, 133–135.

MELAMED, A., BAUER, C. A. & JOHNSON, J. H., 1967. Iliopsoas bursal extension of arthritic disease of the hip. *Radiology*, *89*, 54–58.

1987, *The British Journal of Radiology*, *60*, 1141–1142 NOVEMBER 1987

Short communication

The use of endoscopic ultrasound and laser photocoagulation in the treatment of gastrointestinal tract tumours: early experience

By A. C. Steger, F.R.C.S., S. E. S. Whitecross, M.B., F.R.C.R. and N. Hira, F.R.C.S.

Oldham and District General Hospital, Rochdale Road, Oldham OL1 2JH

(*Received January 1987 and in revised form May 1987*)

In recent years the neodymium yttrium aluminium garnet (Nd:YAG) laser has been used endoscopically to treat inoperable upper and lower gastrointestinal tract tumours. In the oesophagus and gastric cardia, malignant stenoses have been recanalised with a lower complication rate than dilation or intubation and probably with better symptomatic relief (Bown, 1986). In the rectum (and lower sigmoid), bleeding and diarrhoea from tumours have been controlled and stenosis and obstruction have been relieved (Bown et al, 1986). This laser technique is of great value in treating elderly patients, unfit and inappropriate for surgery.

A more recent development is that of fibreoptic endoscopic ultrasound. Here a side-viewing flexible fibreoptic endoscope has a rotating ultrasound generator at its end, and, once positioned, can image from the lumen outwards at varying depths. This has been used successfully to stage oesophageal cancers with regard to depth of invasion and the difficult problem of mediastinal lymph-node involvement (Takemoto et al, 1986). Gastric and rectal cancers have been similarly staged.

The combination of these two techniques, the one investigative and the other therapeutic, raises new treatment possibilities. These include tumour staging after laser recanalisation, laser therapy on the basis of endoscopic ultrasound and the ability to do these via natural routes, relatively non-invasively with reasonable specificity.

EQUIPMENT

The laser used was a Pilkington Medical System Fibrelase 100 Nd:YAG laser. Laser treatment was via low-power contact probes (Surgical Laser Technology, Keighley, Yorkshire). The endoscope with the ultrasound transmitter was an Olympus GF-UM2. This was connected to the Olympus EU-M2 ultrasound display unit. When used in the oesophagus or rectum, a balloon surrounding the ultrasound generator was inflated with water to get an air-free contact with the lumen wall. In the stomach, water was instilled to facilitate a similar air-free contact.

CLINICAL DETAILS

Details of three representative cases are given.

Case 1

A 74-year-old woman was investigated for recurrent iron-deficiency anaemia and gastrointestinal tract bleeding. Gastroscopy showed a large polypoid lesion high on the lesser curve, 5 cm below the cardia. Biopsies were taken. The lesion was treated with 300 J of laser energy to reduce blood loss whilst awaiting biopsy reports. Endoscopic ultrasound confirmed the site of the lesion but the size, 2.2 cm × 2.5 cm, was larger than the endoscopic appearance suggested. The polyp appeared to be within the gastric lumen and did not appear to penetrate through the submucosa. Biopsy reports indicated suspicions of malignant change. In view of the size and the pathology, the lesion was removed at laparotomy. Further examination confirmed a gastric cancer in a polypoid adenoma with no invasion at the base. Blood loss between endoscopy and surgery was stopped.

Case 2

An 81-year-old man presented with rectal bleeding. On rectal examination a tumour was palpable. In view of concomitant medical illness, he was considered unfit for major surgery. Flexible sigmoidoscopy showed a tumour starting at 10 cm. Endoscopic ultrasound confirmed this and showed enlarged low pararectal lymph nodes. The instrument could not be passed through the malignant stricture. After laser recanalisation, the fibreoptic ultrasound endoscope could be passed to 18 cm, identifying a main tumour mass at 15 cm, and showing what was not visible endoscopically, that the whole bowel was encased in tumour at this level. Here, symptomatic relief was achieved and, after recanalisation, further staging suggestive of spread reinforced the decision to avoid major surgery with its risks and to use laser palliation instead.

Case 3

A 57-year-old patient with chronic bronchitis with a history of pleurectomy for recurrent pneumothoraces and treated congestive cardiac failure, presented with dysphagia. Endoscopy showed that, in the oesophagus, there was nodularity in areas of severe inflammation at 35 cm extending upwards for 3 cm. Endoscopic ultrasound showed mucosal thickening and that the inner border of the mucosa was ill defined, raising the possibility of malignancy. Histology and cytology, however, showed acute inflammation in areas of peptic ulceration, with no evidence of malignancy.

DISCUSSION

The combination of concurrent ultrasonic endoscopic investigation and laser endoscopic treatment in one session in a patient is quite possible. To achieve the best results requires the presence of both the laser endoscopist and ultrasonographer—the one cannot satisfactorily replace the other's expertise. The time required for such procedures is longer than the normal endoscopy, or endoscopy with laser therapy. Changing of endoscopes, necessary as the endoscopic

---

Address for correspondence: Mr A. C. Steger, National Medical Laser Centre, Department of Surgery, Rayne Institute, University College Hospital, London WC1E 6JJ.

ultrasound is a side-viewing instrument with no instrument channel, means that the patients require more and sometimes heavier sedation. The advantages, as illustrated by Cases 1 and 2, are immediate staging and treatment.

Before endoscopic ultrasound and laser photocoagulation are performed, however, routine endoscopy and biopsy must be carried out for, as Case 3 illustrates, the combination of a malignant-looking stricture at endoscopy plus an endoscopic ultrasonographic abnormality is not enough on which to proceed to laser therapy.

That the techniques can be combined is evident. The important question is whether or not the expense of the equipment will lead to improved treatment of patients or merely the "high-tech gadgetry" with which to play. We feel that, using the best features of each, there will be improved treatment. Laser therapy has a low complication rate and provides treatment at endoscopy, for either palliation or pre-operative relief (Bown, 1986).

Endoscopic ultrasound defines the extent of a malignant stricture (or lesion) and permits staging of the disease at the time of palliation in areas where pre-operative staging has been notoriously difficult (Takemoto et al, 1986). Computed tomography is useful in staging oesophageal lymph-node involvement, but not in depth of tumour penetration through the oesophageal wall, and is difficult to apply and to interpret in the confinement of the bony pelvis with regard to tumours (Benyon et al, 1986; Riskin et al, 1986).

The combination of laser endoscopy and endoscopic ultrasound should be complementary leading to quicker staging and treatment of gastrointestinal tract tumours than can be provided by either technique on its own, and less invasively than is presently the case.

Acknowledgments

We thank Keymed for the generous loan of the endoscopic ultrasound system and Mrs S. Griffin for typing the manuscript.

REFERENCES

Benyon, J., Foy, D. M. A., Temple, I. N., McMortenson, N. J., Virjee, J. & Goddard, P., 1986. Assessment of local invasion in rectal carcinoma—a comparative study of endoluminal ultrasound and computed tomography. *Gut, 27*, A617.

Bown, S. G., 1986. Endoscopic laser therapy for oesophageal cancer. *Endoscopy, 18 (Suppl. 3)*, 26–31.

Bown, S. G., Barr, H., Matthewson, K., Hawes, R., Swain, C. P., Clark, C. G. & Boulès, P. B., 1986. Endoscopic treatment of inoperable colorectal cancers with the Nd:YAG laser. *British Journal of Surgery, 73*, 949–952.

Riskin, M. D., McGlynn, E. T. & Marks, G., 1986. Endorectal sonographic prospective staging of rectal cancer. *Scandinavian Journal of Gastroenterology, 21 (Suppl. 123)*, 99–103.

Takemoto, T., Ito, T., Aibe, T. & Okita, K., 1986. Endoscopic ultrasonography in the diagnosis of oesophageal carcinoma, with particular regard to staging for operabilities. *Endoscopy, 18 (Suppl. 3)*, 22–25.

Correspondence

(The Editors do not hold themselves responsible for opinions expressed by correspondents)

Increased potential for tissue discrimination in quantitative magnetic resonance imaging

The Editor—Sir,

A method has been developed that substantially increases quantitative tissue discrimination of pathology in *in-vivo* magnetic resonance (MR) imaging. Results from a study of carcinoma and benign hypertrophy of the prostate show the potential for classification of tissues from individual patients and demonstrate increased class separation. This appears to be the first application of pattern recognition techniques to relaxation-time data from *in-vivo* MR images. Multiple-point relaxation-time maps were classified using both statistical measures and texture descriptors derived from spatial grey level dependency matrices. These parameters were combined in a new pattern-recognition method based upon the Karhunen-Loève expansion.

Multiple-point T_1 and T_2 relaxation time and proton density maps of the prostate were produced using seven saturation-recovery and six spin-echo images (Hickey et al, 1986). Such relaxation-time maps have demonstrated clinical utility (Jenkins et al, 1985; Isherwood et al, 1986; Jenkins et al, 1987; Johnson et al, 1987) and contain most of the information available in the source images. All the images were obtained on a Picker International general-purpose MR scanner with a superconducting magnet operating at 0.26 T. Two-dimensional Fourier transform reconstruction was used throughout. Image processing was performed on the 32-bit Perkin Elmer computer in a Picker stand-alone viewing system. The software was written in Fortran using double precision. A series of spatial grey level dependency matrices (Haralick, 1979) was calculated using 1–4 pixel spacings and orientations of 0, $\pi/4$, $\pi/2$ and $3\pi/4$ to the phase-encoded direction. From these matrices five texture descriptors (energy, entropy, correlation, inertia and local homogeneity) were calculated (Ballard & Brown, 1982). In addition, a set of statistical parameters was obtained. The statistical parameters included moments of the distributions (mean, standard deviation, skew and kurtosis) and probabilities of a pixel value being greater than specified values (800, 900, 1000, 1100 and 1200 ms for T_1). Classification of the maps was based upon the N-dimensional space defined by the descriptors. The descriptor values from an individual map form a measurement vector.

The population of measurements was subject to a Karhunen-Loève (K–L) expansion. This expansion gives an optimal (least square) description of the data for a reduced number of parameters (Tou & Gonzalez, 1974). In our application, however, the aim was to demonstrate the potential for image analysis in quantitative MR, not feature extraction. The most important condition for optimisation is that the expectation of the measurements is zero (Chien & Fu, 1967). This was ensured by normalisation to give zero means. The separation of the sample into classes and the combination of individual class autocorrelation matrices to form the generalised K–L co-ordinate system (Chien & Fu, 1967) was considered inappropriate. The null hypothesis was that the classes are sampled from the same population. This hypothesis removes an objection to normalisation of the means (Tou & Gonzalez, 1974) as it involves just a simple translation of the sample in measurement space.

The eigenvectors of the autocorrelation matrix form the orthogonal K–L basis vectors. Calculation of the autocorrelation matrix was by pre-multiplication of the matrix formed by the individual measurement vectors by its transpose (Tou & Gonzalez, 1974). Eigenvectors were calculated using the Householder method followed by a shifted QR procedure (Ralston & Rabinowitz, 1978). Rapid methods for calculating a subset of the K–L vectors are available (Karhunen & Oja, 1982).

Direct analysis of the measurements is complicated by correlation between parameters. The scalar products of the measurement vectors and the orthogonal K–L basis vectors, however, yield N sets of uncorrelated parameters, C (Young & Calvert, 1974). For each basis vector, the eigenvalues equal the expectation of the squared C values and are related to the variance. The K–L basis vectors, when ranked by decreasing eigenvalue magnitude, produce a co-ordinate system in which projections onto each successive axis yield decreasing amounts of information (Young & Calvert, 1974). Nearly all the information is, therefore, contained in the first few basis vectors. The ranking is not expected to relate directly to the discriminative importance of each successive basis vector. The statistical independence and the orthogonality of the co-ordinate system can, however, be utilised for discrimination.

We analysed images from nine patients with prostatic carcinoma and seven patients with benign prostatic hypertrophy. These data were from a group of patients with clinical evidence of prostatic enlargement, who subsequently had surgery and histological confirmation of their disease. The T_1 data obtained from this group using the standard method were particularly unpromising, as the tumour and benign tissues had identical mean values (Johnson et al, 1987). Recent multiple-point clinical relaxation-time measurements at 1.5 T have also suggested that relaxation-time measurements had no clinically useful role in prostatic disease (Kjaer et al, 1987).

The T_1 maps of the prostate were therefore chosen to give a stringent test of the new method. The new class means were, however, not separable on Student's t-test ($p > 0.05$). The group with benign prostatic hypertrophy included patients with predominantly fibrotic or glandular stromal enlargement. Following analysis of only the first 20 statistical measurements per T_1 map of the prostate, we obtained highly significant discrimination between the two classes ($p < 0.001$). For each set of C values, a Student's t-test was used to indicate a probability of separation for the K–L basis vector. These independent probabilities were evaluated using the binomial distribution. This data enabled 14 of the 16 T_1 maps to be classified accurately into their respective groups. The accuracy of this classification could be increased if data from T_2 or M_∞ maps were also incorporated into the analysis.

The image analysis method described here is expected to yield increased tissue discrimination in clinical MR, with the important potential for accurate diagnostic classification of tissues from individual patients. Results reported here indicate an opportunity for wider clinical application.

Yours etc.,

D. J. PRENDERGAST
D. S. HICKEY
J. P. R. JENKINS
I. ISHERWOOD

Department of Diagnostic Radiology,
University of Manchester Medical School,
Stopford Building,
Oxford Road,
Manchester M13 9PT

(*Received June 1987 and in revised form July 1987*)

REFERENCES

BALLARD, D. H. & BROWN, C. M., 1982. *Computer Vision* (Prentice-Hall, New York), pp. 186–188.

CHIEN, Y. T. & FU, K. S., 1967. On the generalised Karhunen-Loève expansion. *IEEE Transactions on Information Theory*, , 518–520.

HARALICK, R. M., 1979. Statistical and structural approaches to texture. *Proceedings of the IEEE*, *67*, 786–804.

HICKEY, D. S., CHECKLEY, D. R., ASPDEN, R. M., NAUGHTON, A., JENKINS, J. P. R. & ISHERWOOD, I., 1986. A method for the clinical measurement of T_1 and T_2 relaxation times in magnetic resonance imaging. *British Journal of Radiology*, *59*, 565–576.

ISHERWOOD, I., HICKEY, D. S. & JENKINS, J. P. R., 1986. Magnetic resonance imaging: an approach to tissue characterisation using measured relaxation times. *Excerpta Medica International Congress Series 698* (Elsevier Science Publishers, London), pp. 27–35.

JENKINS, J. P. R., HICKEY, D. S., ZHU, X. P., MACHIN, M. & ISHERWOOD, I., 1985. MR imaging of the intervertebral disc: a quantitative study. *British Journal of Radiology*, *58*, 705–709.

JENKINS, J. P. R., BRAGANZA, J. M., HICKEY, D. S. ISHERWOOD, I. & MACHIN, M., 1987. Quantitative tissue characterisation in pancreatic disease using magnetic resonance imaging. *British Journal of Radiology*, *60*, 333–341.

JOHNSON, R. J., JENKINS, J. P. R. & ISHERWOOD, I., 1987. Magnetic resonance imaging in oncology. In *Investigative Techniques in Oncology*. Ed. by N. M. Bleehen (Springer-Verlag, London), pp. 125–151.

KARHUNEN, J. & OJA, E., 1982. New methods for stochastic approximation of truncated Karhunen-Loève expansions. In *Proceedings of the 6th Conference on Pattern Recognition*, pp. 550–554.

KJAER, L., THOMASEN, C., IVERSEN, P. & HENRIKSEN, O., 1987. *In vivo* estimation of relaxation processes in benign hyperplasia and carcinoma of the prostate gland by magnetic resonance imaging. *Magnetic Resonance Imaging*, *5*, 23–30.

RALSTON, A. & RABINOWITZ, P., 1978. *A First Course in Numerical Analysis, 2nd edit.* (McGraw-Hill, London), pp. 521–536.

TOU, J. H. & GONZALEZ, R. C., 1974. *Pattern Recognition Principles* (Addison-Wesley, New York), pp. 271–282.

YOUNG, T. Y. & CALVERT, T. W., 1974. *Classification, Estimation and Pattern Recognition* (Elsevier, New York), pp. 223–228.

1987, *The British Journal of Radiology*, *60*, 1144–1146

Proceedings of The British Institute of Radiology

Picture Archiving and Communications Systems (PACS)

Abstracts of papers presented at the above meeting, organised by the Industry Committee of the BIR, held at the Edward Lewis Lecture Theatre, Middlesex Hospital Medical School, Windeyer Building, London W1, on Wednesday, February 25, 1987

Chairman: Professor I. Isherwood

Imaging and the patient, by O. Craig. No abstract received

Image display technology:
Basic introduction to display technology, by D. G. Rothery
Pattern recognition image interpretation, by C. J. Taylor. No abstract received
Image analysis: what the radiologist requires, by W. R. Lees
Image analysis: what is available today, by B. Dalton
Economics of CR-PACS versus conventional systems, by R. Rupprecht

Image transmission systems:
Imtran revolution, by H. Griffiths. No abstract received
Long-distance telemedicine, by L. A. Gillanders
Industrial overview, by P. Vernon. No abstract received

Image storage:
Needs of the NHS, by C. W. Robertson
Image archiving and communications within hospitals, by J. Tiemann
Product-related advantages of a structured Siemens PACS architecture, by C. F. C. Greinacher

BASIC INTRODUCTION TO DISPLAY TECHNOLOGY

D. G. Rothery

3M UK PLC, Bracknell, Berkshire

As predicted by Capp in 1981, medical diagnostic imaging is rapidly converting to electronics for the acquisition of image data. However, the total electronic imaging department of the future will not become a reality until the problems of displaying and viewing electronic images are solved.

The ability to manipulate an image viewed on a television-based system has increased the dynamic viewing range enabling a "linear" electronic sensitometric curve to be produced. The parameters to be addressed in viewing the image are the resolution needs of each acquisition modality, the ability to display the entire image and therefore the pixel size and pixel matrix. Grey-scale reproduction is poor, usually being 8 or 10 bits deep (256 or 512 shades of grey). The display must also be "flicker free": quite a major technical problem. The physical layout and ergonomics associated with a multidisplay work station have been analysed for various applications; some of these can be adapted for radiology.

The alternative to viewing images directly via a monitor display is to make a high-resolution hard copy. This will, to some degree, negate the display resolution limitations. The current trend is to use a laser imaging device to provide a film-based hard copy. Digital interfaces can link the laser imager to the acquisition equipment's computer, thereby extracting all information without electronic signal loss or noise. The absence of phosphor grain, monitor drift and screen distortion further increases the resolution capabilities of such hard copy devices.

The impact of the electronic image display will bring changes to departments in terms of diagnostic capabilities, which should increase, together with better overall productivity. The challenge is in maintaining tomorrow's imaging needs, while satisfying medical and financial restraints.

REFERENCE

Capp, M. P., 1981. Radiological imaging—2000 AD. *Radiology*, *138*, 541–550.

IMAGE ANALYSIS: WHAT THE RADIOLOGIST REQUIRES

W. R. Lees

Middlesex Hospital, London

The radiologist's requirements for a PACS system vary enormously depending on the types of images to be reviewed, and split very broadly into two distinct categories. First, the digital reproduction of conventional radiographs, where the requirement is to preserve the contrast and spatial resolution of the original and if possible to enhance contrast resolution in difficult areas. Second, those images such as CT, MRI and ultrasound which have been digitally acquired and processed and have a much lower resolution requirement in the final display, but often a much higher radiological information content.

The radiological information content of a radiograph varies from practically zero in the case of a normal chest radiograph to a full statement of anatomy and morphology in the case of whole-body CT. The high utility of such studies derives from the way the information was initially acquired and processed rather than anything relating to the final display.

Conventional radiographs require preservation of the full range of spatial and contrast resolution to resolve the smaller features which may be of vital diagnostic importance, such as the exact configuration of branch ducts on a cholangiogram or pancreatogram, or subtle markings on a chest radiograph. Many studies have been performed comparing radiographs digitised to various degrees of resolution with the original and it can be concluded that the radiologist's work-station must fulfil a number of requirements. The absolute minimum resolution is 1024 by 1024 with presentation of at least 8 bits of contrast resolution being taken from a stored image base of at least 12 bits.

Although these minimum requirements result in no significant loss of diagnostic information, the necessary zooming and windowing slows down the reporting process considerably and a much higher specification will be required in routine working practice.

The speed of accessing the stored images must be very high, with an image refresh rate at the console of better than half a second if the radiologist is not to be slowed down. It is also vital that the images are in a properly ordered sequence and that the reports and clinical information should be linked. Multiple display screens are required and comparison of a sequence of film or of different types of study, such as a CT and barium examination, should be no more difficult than current manual film-handling methods.

Apart from simple zooming and windowing facilities, which largely compensate for poor radiography (*i.e.* a radiograph taken under difficult circumstances, such as portables and casualty radiographs), there is unlikely to be a significant need for sophisticated image-processing facilities.

The viewing conditions at the work station must be good. With current CRT technology this will involve working in very subdued lighting and this may well limit the effective spread of such terminals into the clinical areas of the hospital.

IMAGE ANALYSIS: WHAT IS AVAILABLE TODAY

B. Dalton

GEC Research Ltd, Hirst Research Centre, Middlesex

The fundamental limits of the human visual system and the effects of quantum statistics on film resolution combine to reduce the data storage and management problem of radiological images to a realistically usable level. A comprehensive range of image processing techniques is discussed and demonstrated. These included the following.

1 General man–machine interface tools for mensuration.
2 Windowing and thresholding.
3 Edge enhancement and region growing.
4 Three-dimensional displays.
5 Colour, both false and to display multiple parameters.
6 Display of dynamic images (blood flow through the heart and aorta).

ECONOMICS OF CR-PACS VERSUS CONVENTIONAL SYSTEMS

R. Rupprecht

Eastman Kodak, European Region

Eastman Kodak has asked an external company to carry out a survey in the United States on the advantages and disadvantages of an all-electronic radiology department versus a film-based radiology department. The purpose of this presentation is to discuss the results of this survey which can also be described as "costs and benefits of emerging systems, *e.g.* computed radiography and picture archiving and communication system, versus current imaging systems". The three key factors in the evaluation of any new product are clinical performance, organisation and economics.

Clinical performance. Despite the apparent preoccupation with cost containment, clinical efficacy and patient care are still of paramount importance. Radiologists are not willing to accept 500-line CRT resolution and clinicians are not willing to accept lower-resolution displays than those used by radiologists. First-generation systems featuring 2000 × 2000 CR acquisition matrices and 500- or 1000-line displays have shown promising clinical results. However, performance will have to be improved to provide complete equivalence to current radiological products and practices as radiologists are not willing to compromise on image quality.

Organisational aspect. High capital costs may be incurred in order to maintain the preferred organisational structure of a decentralised department, with convenient placement of full resolution image review sites and CR scanning equipment. Interfacing of PACS to imaging equipment and information systems and system reliability are both critical factors with negative implications for system cost.

Economics. Even conservative estimates place the cost of PACS implementation equivalent to over 2 years' capital budget. The primary concern is whether the funds can be put to better use via the purchase of an MRI unit, upgrading surgical suites or improving other areas of the hospital that may have a more direct effect on patient care.

In conclusion, the opportunity for a successful implementation may exist, if a system can be configured to meet department needs and fulfil the first-order critical attribute of increased clinical efficacy and improved patient care. First-generation systems show promise but much work must be done to meet the price and performance thresholds required for hospital acceptance.

LONG-DISTANCE TELEMEDICINE

Lewis A. Gillanders

Aberdeen Royal Infirmary

The role of slow-scan television (SSTV) as a medium for providing expert medical advice to those working in remote, isolated and hostile environments is described and illustrated by videotape recordings of intercontinental analog transmission of radiographs via satellite communications and standard telephone lines from the Memorial University of Newfoundland and British Antarctic Survey Ships to the Centre for Offshore Health in Aberdeen. One major limitation is apparent. Since the resolving capacity of SSTV systems is far below the 4000 × 3000 picture elements encompassed in a 43 cm × 35 cm radiograph resolving 4 line pairs/mm, images of radiographs of a body trunk requiring this size of film are indistinct, and unsuitable for the appreciation of fine and subtle pathology. However, this adverse feature can be overcome by an appropriate television camera procedure, particularly optical magnification (up to × 16) of selected areas of the radiograph, optimal setting of the aperture "stop" and (where necessary) intense illumination of dense areas of the radiograph. These points are illustrated using radiographs of the chest, abdomen, bones and joints.

Slow-scan television is a convenient and inexpensive method of image transmission; its application in clinical radiology has yet to be determined. Its current dependence on a time-consuming camera procedure (preferably under the direct remote control of the receiving radiologist) to capture an image resolved sufficiently for detailed and critical analysis is a decided limitation which is likely to restrict its use for the transmission of images of radiographs, as against images such as CT which employ a relatively coarse matrix.

NEEDS OF THE NHS

C. W. Robertson

DHSS Supplies Technology Division

Given the technical capabilities of PACS, it is instructive to consider how different needs in the NHS might be fulfilled by the adoption of such systems. X-ray departments such as that at St Mary's Hospital, London, where the intensive study was done, are not typical of the departments where most of the X-ray rooms in the NHS are to be found. Departments commonly comprise no more than three X-ray rooms. Also, the organisation of the NHS under 14 autonomous health regions and 192 health districts (in England alone) does not immediately suggest that there would be unanimous agreement about the criteria of need against which the adoption of a PACS would be justified.

This paper attempts to classify the possible needs (medical, technical, social etc.) and to compare them with the properties of PACS. Obviously, there are no conclusions, but the discipline does expose the fact that the properties of PACS may not be perceived as equally beneficial in all circumstances. For example, the property of increased patient throughput may be seen as medically beneficial, but might not be equally welcome managerially, at least in the short term, if it increased the total costs arising from dealing with more patients in the hospital as a whole. On the other hand it might be economically welcome in designing a new hospital to provide a given standard of health care, if it reduced the scale of provision needed for the planned patient throughput.

It seems reasonably clear from the studies at St Mary's Hospital that a major factor in the cost of a PACS is the number of viewing terminals provided. Thus, for example, the advantages of holding images on optical discs and transmitting retrieved images electronically may not be affordable without modifying the traditional concepts of the numbers of different places where images need to be viewed.

In practice, it seems likely that the best prospect for the introduction of PACS advantageously into the NHS would lie with systems capable of progressively phased introduction and also with those in which smaller systems would not be disproportionately expensive as compared with the larger systems. This suggests a modular approach as regards both the scope and the size at which a system can be implemented.

PRODUCT-RELATED ADVANTAGES OF THE STRUCTURED SIEMENS PACS ARCHITECTURE

C. F. C. Greinacher

Siemens AG, Medical Group, Erlangen

Digital imaging methods will be introduced more and more in the routine of radiological imaging departments. Today about 25% of all diagnostic examinations are performed digitally. Technical concepts for integrated image information systems are required to improve routine work and diagnosis. Subsystems for image transport via local area networks, image storage on magnetic and optical storage devices and digital work-stations for image display and interpretation are being developed. Such systems are categorised under the acronym PACS. This paper describes the Siemens PACS, a system that provides technical solutions to support the workflow in a modern hospital. Based on the needs of the structured organisation of the hospital, the Siemens PACS is structured too. This architecture meets the quantitative and qualitative requirements of the hospital and provides additional features such as feasibility of system engineering, customising, stepwise introduction of the system into the daily routine and fail-safety of the system.

BIR Bulletin

November 1987

Company director is new President

Grahame Mountford, the new President of the Institute from October 1, 1987, is a Director of Agfa-Gevaert Limited, where he is Head of the Diagnostic Imaging Systems Division. He is a graduate member of the Institute of Marketing Management, and a member of the British Institute of Management. He also holds the Diploma of Membership of the Communications, Advertising and Marketing Society, and the Diploma of the College of Radiographers.

On leaving grammar school at the end of the last war, Grahame trained as a physiotherapist before serving a short commission in the Royal Navy. In Naval service he was attached to the Royal Marine Commando Unit at Lympstone, the staff of Flag Officer Air Home, and the Flag Officer Royal Yachts. After leaving the Navy he qualified as a radiographer and took up various senior and superintendent appointments at hospitals in Chelmsford and London. In 1957 he joined Ilford Limited, where he remembers working under the direction of Miss K. C. Clark (author of *Positioning in Radiography*) at Tavistock House. In 1963 he transferred to Agfa Limited at Wimbledon where, after a short period, the company merged with the Belgian company of Gevaert to form the new company of Agfa-Gevaert. After the retirement of Mr Bill Kirby in 1968, Grahame took the post of Medical X-ray sales manager, and in 1978 he was promoted to divisional manager of the newly formed Medical, Industrial and Scientific departments. He was recently made a director of this now much enlarged division of the company.

Within the BIR, Grahame joined the Industry Committee in 1977, and in 1980 was appointed Secretary to the Scientific Committee and elected to the Council. In 1982, when Her Majesty the Queen opened the new premises of the BIR at Portland Place, Grahame was among members of the Council to be presented to Her Majesty. He has served as a Vice-President since 1984, is now Chairman of the Industry Committee, and serves on various committees and working parties of the Institute. He has been Director of the Technical Exhibition at the BIR Congress since the larger congresses started in 1985.

Outside the Institute, he is Chairman of the Photographic Association (BPA) X-ray Committee, and sits on the British Health Care Trade and Industry Council. He lives in New Malden with his wife, Jenny, who is a Personnel Officer at the BBC. His hobbies include photography, gardening and classical music, where he has a keen interest in Mozart and has a large collection of his works. He is a member of the London Mozart Society.

It is only the third time in 90 years that the Institute has had an "Industry" President, the last being Mr Harry Grover in 1969, and before that, Mr Cuthbert Andrews in 1953.

1987 Nycomed Scholarship Reports

Dr James Gillespie and Dr Andrew Platts, two of the winners of the 1987 Nycomed Scholarships, spent February–March and May–June 1987 respectively, in radiology departments in Scandinavia. This month's *Bulletin* features their reports.

DR A. PLATTS

Supported by a Nycomed Scandinavian Scholarship, I was recently able to spend 2 months observing the work in the radiology departments in Lund University Hospital, Sweden, and Copenhagen County Hospital at Herlev in Denmark.

Lund

The Department of Radiology in Lund is situated centrally within the main block of the hospital, reflecting the status of the radiology unit within the hospital. Most of my time was spent watching the work of the abdominal division, but I was also able to spend some time with the Department of Neuroradiology.

The abdominal division is lead by Anders Lunderquist, whose work and reputation are familiar to British radiologists. The profile of work that is performed in the department is probably similar to that in any busy gastroenterology department, but it was interesting to find that almost everything is done in a slightly different way to what one would expect in Britain. For example, in the angiography section, pre-formed catheters are not normally used and it was pleasing to see the obvious satisfaction that people derive from shaping their own catheters using hot water and copper wire. In the barium screening rooms, nasogastric intubation is routinely used for double-contrast examination of the stomach. The lasting impression I have of the interventional work will be of Dr Lunderquist's extraordinary ability, and attention to fine detail exemplified by his care in selection and measurement of catheters, positions and sizes of side-holes and the constant quest for improvements in technique and contrast media.

Dr Lunderquist provided me with a recipe for a contrast medium to opacify the bowel during computed tomography (CT). This, he claims, will reliably opacify the gut from the stomach to the rectum within an hour. We have used this mixture in the CT department of the Royal Free Hospital since my return, and we can confirm that it works well. The recipe is as follows:

1 l water
35 ml Gastrografin
50 ml 70% sorbitol
(we add orange squash to flavour)

A quarter of the mixture is given every 15 min for 1 hour before the scan. The osmotic effect of the sorbitol displaces bowel gas and distends the bowel loops. We have found that most patients will have a single episode of osmotically induced diarrhoea, usually within 1 h of completion of the study. We therefore advise them not to leave the department until this has occurred. Despite this, it is well tolerated.

I was surprised to find that percutaneous biliary endoprostheses were hardly ever used, external/internal biliary catheters being preferred for transhepatic drainage.

There is an active radiological research department with exciting work being carried out by Dr Krasnodor Ivancev, who is investigating a contrast medium for hepatic parenchymal and vascular enhancement in CT use.

The neuroradiology division is lead by Sten Cronquist and is an extremely friendly, well run, and well equipped department. In addition to the routine work there is a fascinating prospective study under way, investigating the use of magnetic resonance imaging (MRI) in acute cord compression. The machine is a Fonar 0.3 T hybrid system with a vertical field. This has a very large scanning tunnel, which allows excellent access to the patient so even very ill patients can be scanned. These patients have been difficult to examine in the supercooled horizontal field machines with which I have worked, because the narrow tunnel has severely restricted access.

I had an interesting time in Lund, a beautiful old university town with many museums. My main distraction was superb windsurfing on the sea about 8 miles away. Southern Sweden has many lovely beaches which shelve slowly, and indeed in some places you could stand on the bottom up to 2 km off shore. I was able to take my car to explore the southern part of Sweden known as Skane. It really is very beautiful with many medieval castles and lovely farmhouses. The scenery is rather flat and reminiscent of parts of northern France. I was also made very welcome by Steven Frost and his wife. Steven is an English graduate who has been training in radiology in Sweden for 5 years. Steven also supported my protestation to some of the Swedish members of the radiology department that not all English people sleep under the railway bridges at Waterloo station!

Copenhagen

From Lund I moved to the County Hospital at Herlev in Copenhagen where I worked with Flemming Burcharth, head of the Department of Surgical Gastroenterology and Professor Thorkild Mygind, head of the Department of Radiology. The main interest here is in hepatobiliary radiology.

Although Flemming Burcharth is a surgeon, he has devised and developed several "radiological" techniques. In addition to my time in the radiology department, I was able to attend the operating theatre and watch hepatic resection and surgical biliary drainage procedures.

In the radiology department I initially observed and assisted Professor Mygind, though later he allowed me to perform some procedures under his supervision. I gained some experience of their technique of biliary drainage using a fine mandril guidewire, inserted through the Chiba needle followed by coaxial dilatation. I again have applied this technique with success at the Royal Free Hospital. I was most impressed with Professor Mygind's management of his patients. His concern for their care is expressed in his thorough explanations to the patient and effective control of pain with analgesia and sedation.

I was able to see some complex biliary problems tackled jointly between the radiologists and surgeons, confirming that they can only successfully be managed by very close co-operation. The uroradiological interest at Herlev was looked after by Dr Sven Dorph and I was also able to watch his work, which included renal angioplasty.

Socially, the delights of Copenhagen will, I am sure, need no introduction. There is wonderful windsurfing, particularly on the North coast of Zeeland at Hunerstead and Rovig, and closer to Copenhagen on the straits of Denmark. The Tivoli gardens were in bloom but more beautiful were the spring colours of the beech forest just north of Copenhagen. Here, within a few miles of the centre of Copenhagen, herds of deer roam and red squirrels still survive, making me realise how unattractive our grey type are.

Summary

In conclusion, the time I spent in Scandinavia was extremely rewarding. I found the people in both radiology departments welcoming and charming, and was sorry when my stay came to an end. I was exposed to many new ideas, and saw many different ways of performing procedures to achieve the same goal; I was reminded of this when I asked one of the senior radiographers in the department at Herlev why she had worked in England for 8 years. She quoted an old proverb which says that one must travel to find out whether all letter boxes—like Danish ones—are red, even though after her stay in England she concluded that they were.

Dr J. Gillespie

I spent the entire 8 weeks of this Scholarship at the Sahlgren Hospital in Gothenburg, Sweden's second largest city. During this time I was attached to the neuroradiology section under the direction of Dr Paul Svendsen. The Sahlgren Hospital is one of about six university hospitals in Sweden and acts as a regional centre as well as providing local hospital services for approximately half of Gothenburg. The hospital employs 600 doctors and contains around 1450 beds.

General departmental organisation

The Department of Radiology is located on two floors; the upper floor contains numerous conference/reporting rooms and offices as well as a library, while the lower floor contains the main work area and examination rooms. Radiologists are system- rather than modality-orientated, each section having its own examination and conference rooms. The working day runs from 7.00 a.m. to 4.00 p.m. After 4.00 p.m. there is a resident on-call radiologist who reports on all radiographs and procedures performed after normal working hours.

Neuroradiology

The working day commences at 7.00 a.m. with a review of all the previous day's work, followed by a daily clinical meeting with the ENT clinicians at 8.00 a.m. and the neurologists and neurosurgeons at 8.30 a.m. I found the neuroradiological practice in Gothenburg generally similar to that in Manchester apart from the relatively small volume of non-emergency myelographic work compared to my own practice. This is largely due to the use of computed tomography rather than lumbar myelography for the initial investigation of suspected lumbar disc disease. During my time there, I was free to partake in the routine work of the section. I found this very beneficial and have been able to incorporate some of the minor differences in technique which I observed into my own routine practice.

One afternoon each week was reserved as far as possible for teaching purposes. This took the form of informal group discussions on selected topics, followed by a more formal general departmental lecture. During my stay I presented one of these lectures and gave a further talk to the orthopaedic surgeons.

Interventional neuroradiology

The main purpose of my visit was to observe and, where possible, participate in performing interventional neuroradiological procedures. Dr Svendsen devotes 2 days each week to interventional neuroradiology and performs up to four procedures per week. The Sahlgren Hospital is the main referral centre for interventional neuroradiology in Scandanavia and treats patients from all the Nordic countries. Seventeen procedures were performed during my stay; the range of abnormalities treated comprised intracerebral arteriovenous malformations (AVMs), intracranial dural fistulas, venous malformations of the face and neck, and carotico-cavernous fistulas. Intracerebral AVMs and dural fistulas were usually treated with isobutyl 2-cyanoacrylate (IBCA) injected through a microcatheter positioned near the nidus of the lesion. In the small number of cases where the catheter could not be advanced sufficiently near the nidus, PVA particles were injected as an alternative. Venous malformations of the face and neck were treated by percutaneous injection of absolute alcohol following direct puncture phlebography. Details of their technique have already been published in *Acta Radiologica Diagnosis, 27* (1986), 149–155. Carotico-cavernous fistulae were treated using Debrun detachable balloons.

Towards the end of my stay a course in interventional neuroradiology discussing the indications, risks and complications of these procedures was held in Gothenburg and I was fortunately able to attend. The speakers included two interventional neuroradiologists of international repute, Dr Alex Berenstein (New York) and Dr Jean Jacque Merland (Paris), as well as several eminent Swedish neuroradiologists and clinicians. The course provided an excellent overview of the state of the art in interventional neuroradiology which complemented the practical experience I had gained in the previous 6 weeks.

Social aspects

Gothenburg is a beautiful city containing a large number of museums, theatres, art galleries and parks, in addition to modern department stores and shopping complexes. Despite the wintery conditions present during February and March, I and my family were still able to see much of Gothenburg and the surrounding region. We also travelled by train across Sweden to spend a weekend in Stockholm.

On our final weekend in Scandinavia, we drove down the south-west coast of Sweden to Helsingborg and took the short ferry ride to Helsingor in Denmark where we visited the very impressive Kronberg Castle, better known as Hamlet's Castle. We then drove across Denmark to sail home from the west coast port of Esbjerg.

Conclusion

The Nycomed Scholarship provided me with a unique opportunity to experience neuroradiology as practiced in Sweden as well as invaluable experience in the field of interventional neuroradiology which I intend to pursue in my own hospital. I would certainly recommend other British radiologists to avail themselves of the opportunity offered by Nycomed to visit Scandinavia in the future.

I would like to thank Nycomed for their generosity in funding this scheme and the British Institute of Radiology for organising it. I also wish to thank Dr Paul Svendsen and his colleagues at the Sahlgren Hospital for making my visit a most enjoyable and worthwhile venture.

Barts Megavoltage Radiotherapy 50th Anniversary Conference

In 1937 the Meyer Sassoon, million volt apparatus at St Bartholomew's Hospital first treated patients with megavoltage radiotherapy. This proved a historic landmark in radiotherapy and a watershed in terms of radiotherapeutic potential. No longer was full dose placed on the skin surface, and at last beams with decent depth-dose characteristics could be produced to treat deep-seated cancers. To mark the 50th anniversary, a 3-day international conference was held at Barts.

Professor A. Jones and Mr G. Innes opened the meeting with lectures on the history and development of the million volt unit and showed a video from 1937 of patients undergoing therapy. Professor H. Suit chaired a fascinating session on "precision in radiotherapy" in which all the contributors demonstrated how fast the field has developed since 1937. Drs W. Wara and H. Bloom then led a session devoted to CNS tolerance and results. Multiple papers on CNS brachytherapy demonstrated the current interest in that field. Other subjects tackled over the next 72 hours were:

Abdominal organ tolerance and radiotherapy (Professor K. Trott, Dr S. Arnott)
Current status of electron therapy (Dr S. Klevenhagen, Dr E. Aird)
Paediatric radiotherapy (Dr S. Donaldson, Professor J. Malpas)
Breast conservation (Professor B. Pierquin, Dr M. Spittle)
Interstitial radiotherapy (Dr D. Ash)
Current concepts in fractionation (Dr S. Dische, Dr J. Hopewell)
Response predictors in radiotherapy (Dr L. Peters, Professor J. Fowler)
Quality assurance in radiotherapy (Mrs J. Young)
Xenografts and radiobiology of human tumours (Dr G. Steel)
Ocular radiotherapy (Dr J. Schipper, Dr A. Harnett)
Total body irradiation (Professor A. Barrett, Dr N. Plowman)

Two hundred and seventy-nine delegates from all over the world enjoyed this stimulating 3-day golden anniversary conference, the proceedings of which will shortly appear as a supplement to the *BJR*. At the conference dinner in the Great Hall at Barts, the toast was: "to the next 50 years".

P. N. PLOWMAN

British Radiation Protection Association

Third Annual Report: 1986

The membership of IRPA via BRadPA now stands at 975, an increase of 149 on 1985. Council has met on three occasions during 1986, one more than in 1985, which reflects a steady increase in the amount of radiation protection work being undertaken. A significant proportion of each meeting has been taken up with discussions relating to the Seventh International Congress of the IRPA to be held in Sydney, Australia, in April 1988. The two UK Members of IRPA Executive (Professor J. Lakey and Dr S. Osborn) have been invited to attend meetings of Council for discussions on IRPA matters. Each of them has attended on two occasions and we are grateful for the advice and information they have provided.

BRadPA has considered at length the question of attracting funds enabling BRadPA-nominated delegates to attend the IRPA congress. Financial support is being sought from charitable bodies and from commercial organisations in the UK, particularly in the medical field, that have an interest in radiation protection. During November, Council discussed a proposal from the President of the IRPA that assistance should be provided with the registration fees for the IRPA congress, in Sydney, for nominees from developing countries. The proposal has been passed to constituent societies for consideration.

Council devoted considerable time over a request from Dr Meinhold, Chairman of the Long Range Planning Group of IRPA, who asked for the views of BRadPA on the long term role of IRPA. The Honorary Chairman and Secretary drafted a reply, which after full consultation with constituent societies and further discussions, enabled a detailed response to be sent to Dr Meinhold.

A number of papers relating to the Chernobyl disaster reached Council and there has been a lengthy discussion on the role of BRadPA in nuclear accidents and in providing information. The view was held that BRadPA could fulfil an important role and that pressure should be put on central Government to ensure that arrangements are better in future and that reliable information will be made available. This information should be distributed effectively to radiation protection experts working at local level.

The Standing Rules Committee was asked by Council to recommend how matters requiring an urgent response should be handled. This is in cases where it is clearly desirable for BRadPA council to respond but insufficient time has been allowed for the normal consultative procedure to be followed. The recommendation of the Standing Rules Committee is being considered by constituent bodies.

Some administrative changes have been made during this year. The BIR is still used as the mailing address for BRadPA, although they are no longer able to provide the secretarial assistance which they kindly did during the earlier days of BRadPA. BRadPA wishes to thank Mrs D. Jasper for her work while she was at the BIR and our continued thanks to Miss S. Johnstone for her help and co-operation and to Mrs Angela Lansdown for the work she undertakes for BRadPA. The continued thanks also go to the College of Radiographers who continue to act as hosts for the meetings of the Council.

P. P. DENDY
Honorary Chairman
A. G. RICHARDS
Honorary Secretary

BIR calendar events

Unless otherwise indicated, enquiries about the following events should be addressed to the Conference Manager, British Institute of Radiology, 36 Portland Place, London W1N 4AT (Tel. 01-580 4085).

The meetings are at 36 Portland Place unless otherwise stated. Attendance is open to non-members.

Imaging in Dementia

October 15, 1987 at 5.30 p.m.
Organised by the Diagnostic Methods Committee.
Chairman: Dr P. J. Ell.
Speakers: Prof. R. Levy, Dr R. Wise, Dr P. J. Ell, Dr N. Antoun and Dr I. Moseley.

Chemical Modification of Radiation Effects: Experimental and Clinical

November 13, 1987 at 11.00 a.m.
All-day radiobiology work-in-progress meeting.

New Radiopharmaceuticals and Their Clinical Application

November 27, 1987 at 10.00 a.m.
Scientific Societies, London W1
Organised by the Nuclear Medicine Subcommittee.
Speakers: Dr K. E. Britton, Dr I. Brown, Dr D. Le Bars, Dr P. J. Ell, Dr B. Langström, Dr M. C. Lasne, Dr N. A. Lassen, Dr S. K. Luthra, Dr H. J. Machulla, Dr M. V. Merrick, Dr A. D. Nunn, Dr P. F. Sharp, Dr A. M. Verbruggen and Dr G. D. Zanelli.

Lasers—Applications in Radiology

January 14, 1988 at 5.30 p.m.
Joint BIR/RCR/RSM meeting.
Chairman: Dr W. D. Jeans.
Speakers: Dr A. L. Mackenzie, Dr D. C. Cumberland, Dr S. G. Bown, Mr D. Rothery, Dr G. Watson and Dr S. Hart.

Clinical Usefulness of Nuclear Medicine Image Processing

February 9, 1988
Joint IPSM/BIR meeting organised by the IPSM.
Further details: General Secretary, IPSM, 2 Low Ousegate, York YO1 1QU (Tel. 0904-610 821).

Functional Insights From Magnetic Resonance

February 17, 1988
University College and Middlesex School of Medicine, London, W1
Organised by the Diagnostic Methods Committee.
Chairman: Prof. B. S. Worthington
Speakers: Dr M. A. Smith, Mr D. Longmore, Dr I. Young, Dr D. Hadley, Prof. I. Isherwood, Dr S. Williams, Prof. R. H. T. Edwards, Dr B. Ross, Prof. O. Reynolds, Dr J. Cox and Dr V. R. McReady.

This meeting will incorporate the 1988 **Silvanus Thompson Memorial Lecture**, by Prof. P. Mansfield "Structural and functional investigations by real-time echo planar imaging". This will be open to non-registrants.

Radiobiology All-Day Non-topic Proffered Papers Meeting

February 19, 1988
Organised by the Radiobiology Subcommittee.

Too Much Radiation in Radiodiagnosis?

March 9, 1988
London, venue to be confirmed
All-day meeting organised by the Industry and Radiation Protection Committees.
Chairman: Dr J. G. Russell.

Total-Body Irradiation

April 13, 1988
Joint BIR/IPSM meeting organised by the BIR.

Conversazione

June 23, 1988
Institute of Directors, London SW1
Lecture by Sir George Pollock

RADIOLOGY '88

GLASGOW

23-25 May 1988

The 46th Annual Congress of the *British Institute of Radiology* incorporating the joint Spring Provincial meeting and in collaboration with the Scottish Radiological Society. To be held at the Scottish Exhibition and Conference Centre, Glasgow.

Radiology '88 will be the first in a series of joint ventures with the College of Radiographers. The two complementary though separately organised conferences will be spanned by a joint technical exhibition, MED **X** RAY, which will be Britain's largest radiological technical exhibition.

Radiology '88 will cover the breadth and depth of modern radiology, both diagnostic and therapeutic.

Proffered papers are invited for oral and poster presentation. The poster exhibition will be a major element and posters will be discussed at chaired sessions. Abstract forms available from BIR Conference Office. **Closing date 30 November, 1987.**

Library news

The BIR Library is open weekdays 9 a.m.–5 p.m. (7 p.m. on Thursdays)

The Librarian, Mrs Gunnel Ingham, is in attendance Tuesdays 11 a.m.–5 p.m., and Thursdays 11 a.m.–7 p.m., and Mrs Angela Lansdown, daily 9 a.m.–5 p.m. (Tel. 01-580 4085).

The journal stock includes more than 100 titles. Though journals may not be taken out of the library, there is a photocopy service, also available by post. A list of current journals is available on request and is also published in the March and September issues of the Bulletin. *Most books (excepting the historical collection) are available on loan.*

There is an agreement which allows BIR members limited use of the RSM Library for reference purposes. Members should apply to the BIR Librarian for a visitor's card.

Recent additions to the Library

IAEA: Radiotherapy in developing countries. Proceedings. 1987
Roelandt, J. (Ed.): Digital techniques in echocardiography. 1987
Roth, K.: NMR tomography and spectroscopy in medicine. 1984

Meetings and courses

As a service to our readers, the title, date and place of meetings and contact address will be inserted free of charge: any additional information will be charged at £1.75 per printed line, per insertion. Please contact the Managing Editor.

Nuclear Medicine—Biannual Intensive Course

January 29–30, 1988
UMDS St Thomas's Hospital Medical School Postgraduate Centre, London
Further details: Miss Erica Mendy, Postgraduate Secretary, St Thomas's Hospital, Lambeth Palace Road, London SE1 7EH. Tel: 01-928 9292 ext 2072.

International Congress: Interventional Radiology in Cardiovascular Diseases

February 3–5, 1988
Toulouse, France
Further details: Professor F. Joffre, Service de Radiologie, Chu Rangueil, Chemin du Vallon, 31054 Toulouse Cedex, France. Tel: 6155 4478 ext. 3081-3047.

1st South African Medical Resonance Symposium combined with CT and Radiology Update

February 12–13, 1988
University of Cape Town
Further details: Mrs S. Elliot, Postgraduate Medical Centre, UCT Medical School, Observatory 7925, Cape Town, South Africa.

The Lyon Conference: Computer Science and Life. Medical Imaging and Specialist Systems applied to Medicine

March 10–12, 1988
Ecole Normale Supérieure de Lyon, Lyon
Further details: Package, Les Entretiens de Lyon, 55 montée de Choulans, 69323 Lyon Cedex 05. Tel: 033 78 42 29 53. Telex: 330 295 F.

International London Course in Whole Body Computed Tomography

March 27–31, 1988
Gleneagles Hotel, Perthshire, Scotland
Further details: Mrs J. O'Donnell, Organising Secretary, Royal Marsden Hospital, Downs Road, Sutton, Surrey SM2 5PT, UK.

7th International Congress of the International Radiation Protection Association (IRPA 7): Radiation Protection Practice

April 10–17, 1988
Sydney, Australia
Further details: IRPA 7 Secretariat, GPO Box 2609, Sydney, NSW 2001, Australia (Tel: 02-241 1478, Telex AA74845 "Consec", Cable "Convention" Sydney).

25th Congress European Society of Paediatric Radiology

April 11–16, 1988
Montreux, Switzerland
Further details: Dr M. A. Hopf, 1 Route de Florissant, CH-1206 Geneva, Switzerland. Tel: 4122-47 25 47.

Practical Interventional Radiology 1988

April 25–28, 1988
The Lafayette Hotel, Boston, MA
Further details: Harvard Continuing Education, Boston, MA 02115. Tel: (617) 732-1525.

11th International Congress of Head and Neck Radiology

June 6–11, 1988
Uppsala, Sweden
Further details: H. Wilbrand, M.D., Department of Diagnostic Radiology, University Hospital, S-751 85 Uppsala.

Annual Meeting and Postgraduate Course Arranged by the Cardiovascular and Interventional Radiological Society of Europe and the American Society of Cardiovascular and Interventional Radiology

June 12–17, 1988
West Berlin
Further details: Reingard Sörensen, M.D., Klinikum Steglitz, Röntgendiagnostik, Hindenburgdamm 30, 1000 Berlin 45, Federal Republic of Germany.

2nd European Congress of NMR in Medicine and Biology

June 23–25, 1988
International Congress Center, Berlin
Further details: Conference Secretariat, c/o Prof. Dr R. Felix. Department of Radiology, Charlottenburg University Hospital, Spandaeur Damm 130, D 1000 Berlin 19, Federal Republic of Germany.

Australian Society for Ultrasound in Medicine 18th Annual Scientific Meeting

September 1–3, 1988
Gold Coast, Queensland
Further details: Dr G. O'Brien, 225 Wickham Terrace, Brisbane, Queensland, 4000 Australia.

14th L.H. Gray Conference. Low Dose Radiation—Biological Bases of Risk Assessment

September 11–15, 1988
New College, Oxford
Further details: Dr K. F. Baverstock, MRC Radiobiology Unit, Chilton, Didcot, Oxfordshire OX11 0RD.

4th Jahrestagung der Deutschen Gesellschaft für Lasermedizin

October 5–8, 1988
Vienna, Austria
Further details: Doz. Dr A. Tuchmann, c/o Wiener Medizinische Akademie, Alser Strasse 4, A-1090 Vienna, Austria (Tel. 0222-427 165).

European Joint Committee on Radiopharmaceuticals 3rd Postgraduate Course on Radiopharmacy for Clinicians

October 17–22, 1988
Städtisches Klinikum Berlin Buch, DDR
Further details: Professor Dr H. Deckart, Städtisches Klinikum Berlin Buch, Nuklearmedizinische Klinik, DDR-1115.

International Symposium on Magnetic Resonance Imaging

December 14–16, 1988
New Delhi, India
Further details: Dr N. Prasad, Department of Radiology, Baylor College of Medicine, Houston, Texas 77030, U.S.A. Tel: (713) 799-4415.

Instructor/Assistant Professor
Rhode Island Hospital

The Department of Radiation Medicine of the Rhode Island Hospital, a teaching unit of Brown University, is recruiting for a full-time academic Radiation Therapist. The successful candidate must qualify for a faculty appointment at Brown University at the level of Instructor/Assistant Professor in the Department of Radiation Medicine.

The individual should possess a medical degree and be board certified or eligible. This individual should evidence an expertise in patient care based upon a highly qualified training programme. The person must have demonstrated the capacity for scholarship and is expected to begin an involvement in either basic or clinical research. There should be some comments, in letters of recommendation, regarding the individual's ability to teach, albeit specific documentation of teaching ability may not be required because of the difficulty of access of the Radiation Therapy Department to didactic courses in most medical schools. In addition, the individual must evidence an interest and a willingness to relate to the private sector of radiation medicine and surgical oncology in order to be a major focus of the coordinated research programme utilizing the patient resources of both the full- and part-time voluntary sector at Brown.

The Department opened in 1973, and is staffed by a complement of eight certified Radiation Therapy technologists, and equipped with the latest therapy units, including a 10 MeV, 6 MeV and a 4 MeV linear accelerator. The Department has a Toshiba Simulator with fluoroscopic capability and transverse tomography. Full-time physics staff in the Section of Physics including one PhD physicist and two dosimitrists. The Department has a Section of Computer Sciences with the latest in computer equipment, including PDP 11 and a new VACS 11750 system. The Department also includes a Psychosocial Programme with a liaison psychiatrist and a psychiatric social worker. In excess of 1200 patients a year are treated, and this is expected to increase very closely with the Department of Medical Oncology and with the various surgical subspecialties in combined modality treatment programmes and in Phase II and Phase III cooperative clinical trials, most of which are associated with national and international cooperative groups which the Department is associated with. Basic research opportunities could be made available for those who have a specific interest in laboratory research. The Department of Radiation Therapy is under the direction of Dr. Melvin Tefft.

Inquiries, along with current curriculum vitae, should be directed to Dr. Melvin Tefft. Thereafter, candidates will be asked to visit Providence (at the expense of the Department of Radiation Therapy) for interviews prior to the final selection of this position. Applications must be submitted no later than 31st December, 1987.

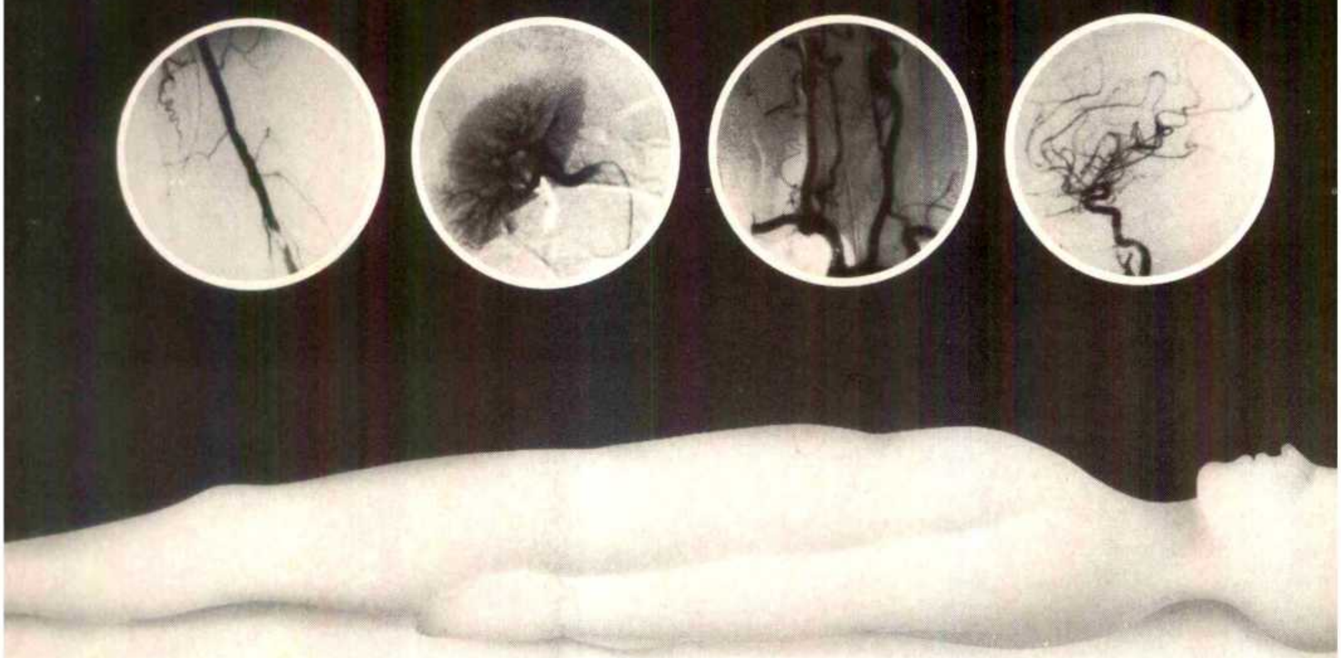
Mailing address:

Department of Radiation Therapy
Rhode Island Hospital
593 Eddy Street
Providence, RI 02903

The Rhode Island Hospital is an EEO/AA employer and invites applications from minority and protected groups.

British Made

Digital Subtraction Angiography



Outstanding Picture Quality at a Low Price

Quantel's totally new concepts in video processing, developed over 15 years for the TV world, make IDIS a truly revolutionary product. Previously time consuming and complicated angiography tasks can now be performed in seconds — and you don't have to be a computer programmer to operate IDIS. As the development costs were borne by the broadcast industry the price for IDIS is surprisingly attractive.

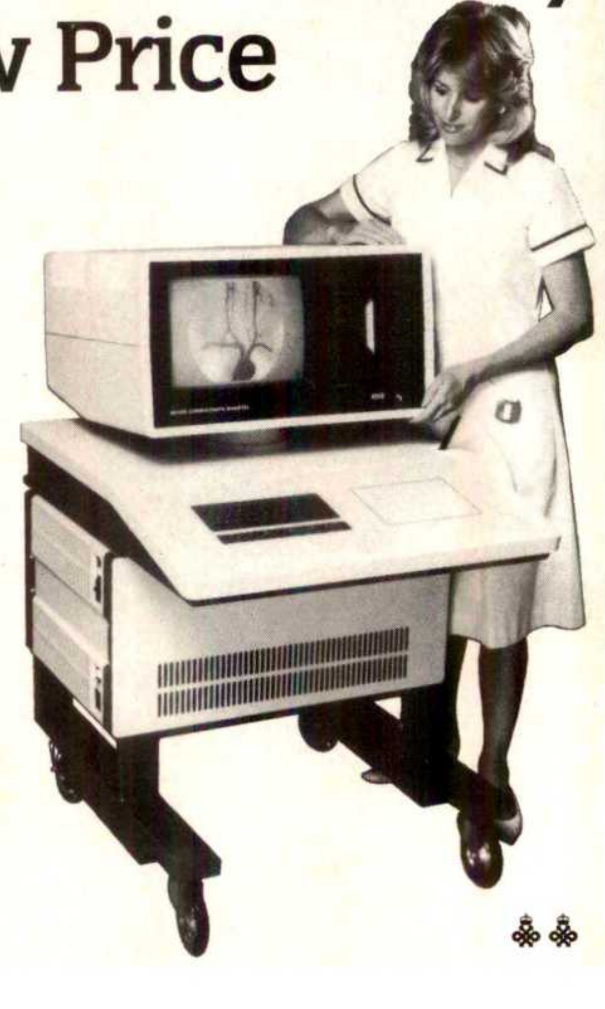
IDIS is easy to install too. All you need is a simple coaxial cable connected to the fluoroscopic output of your system. No air conditioning or special power is needed, just plug it in to a standard domestic socket and IDIS is ready for action. Use of high density multi-layered printed circuits result in a small compact unit — easily wheeled from room to room.

For the technically minded, IDIS uses — Analogue/Digital converters to digitise signals at 10 million samples per sec; Recursive Video Processor for real-time noise reduction; State-of-the-art 32 bit microprocessors for fast digital calculation; 168 Mbyte Winchester disks for vast picture library; new technology 10 Mbyte removable floppy disk cartridges. Features such as Matched Temporal Filtering, Spatial Filtering, Interpolated Zoom and Dynamic Contrast Adjustment give startling picture clarity and versatility to optimise accurate diagnosis.

IDIS leads the field in DSA and is backed by Quantel's world acclaimed service.

– for innovative medical imaging

IDIS



(continued from outside back cover)

Proceedings of The British Institute of Radiology 1144
Picture Archiving and Communications Systems, February 25, 1987

Book reviews

Pediatric body CT. *A. Daneman* 1058
Manual of fetal echocardiography. *L. D. Allan* 1058
Pediatric ultrasonography. *C. K. Hayden Jr and L. E. Swischuk* 1058
Angiocardiography. Current status and future developments. *H. Just and P. H. Heintzen* (Eds) 1062
Pocket atlas of MRI body anatomy. *T. H. Berquist, R. L. Ehman and G. R. May* 1062
Clinical imaging of the pancreas. *G. May and R. Gardiner* 1062
Physics in nuclear medicine, 2nd edit. *J. A. Sorenson and M. E. Phelps* 1066
Diagnostic nuclear medicine: patient studies. *H. N. Wagner, J. W. Buchanan and D. Espinola-Vassallo* 1066
Diagnostic imaging in neurological disease. *I. Moseley* 1082
Diagnostic imaging in surgery. *R. L. Eisenberg* 1082
Advances in immunity and cancer therapy. Vol. 2. *P. K. Ray* (Ed.) 1098
Treatment planning in the radiation therapy of cancer. *J. M. Vaeth and J. Meyer* (Eds) 1098
Organ doses from medical X-ray examinations calculated using Monte-Carlo techniques. NRPB R186. *D. G. Jones and B. F. Wall* 1118
A national survey of doses to patients undergoing a selection of routine X-ray examinations in English hospitals. NRPB R200. *P. C. Shrimpton, B. F. Wall, D. G. Jones, E. S. Fisher, M. C. Hillier, G. M. Kendal and R. M. Harrison* 1118
An update on the frequency of medical and dental X-ray examinations in Great Britain—1983. NRPB R201. *B. F. Wall, M. C. Hillier and G. M. Kendall* 1118
ICRU report 41. Modulation transfer function of screen–film systems 1118
Biochemical mechanisms of platinum antitumour drugs. *D. C. H. McBrien and T. F. Slater* (Eds) 1124
Physical techniques in clinical hyperthermia. *J. W. Hand and J. R. James* (Eds) 1124

BIR Bulletin and calendar events *facing page* 1146

Featured in the next issue

BIR Mayneord Lecture. The Chernobyl reactor accident—the impact on the UK
F. A. Fry

Nuclear reactor accidents: preparedness and medical consequences
Proceedings of a one-day BIR seminar held on April 2, 1987

A quarter of a century ago
The first in a series of occasional articles on the history of radiology, by the Editors

Index to the 1987 volume

VOL 60 NO 719 NOVEMBER 1987

The British Journal of Radiology

Contents

Page

Seeing things more clearly (1986 Mayneord Lecture) 1049
G. R. Higson

A review of cervical-spine radiographs in casualty patients 1059
J. A. D. Annis, D. B. L. Finlay, M. J. Allen and M. R. Barnes

Real-time ultrasound measurement of bladder volume: a comparative study of three methods 1063
G. G. Hartnell, E. A. Kiely, G. Williams and R. N. Gibson

Percutaneous gastrostomy and gastro-jejunostomy 1067
R. R. Gray, E. L. St Louis and H. Grosman

Evaluating and comparing imaging techniques: a review and classification of study designs 1071
L. S. Freedman

The accuracy of digital subtraction angiography for the quantification of atherosclerosis 1083
H. Key, P. C. Jackson, E. A. Thomas, W. D. Jeans and E. R. Davies

The role of technetium-99m pentavalent DMSA in the management of patients with medullary carcinoma of the thyroid 1089
S. E. M. Clarke, C. Lazarus, R. Mistry and M. N. Maisey

Intracavitary irradiation of endometrial cancer of large uteri using a two-phase afterloading technique 1093
A. Kauppila, P. Sipilä and A. Koivula

The influence of field size on the late tolerance of the rat spinal cord to single doses of X rays 1099
J. W. Hopewell, A. D. Morris and A. Dixon-Brown

Dose-dependent and time-dependent changes in the choroid plexus of the irradiated rat brain 1109
W. Calvo, J. W. Hopewell, H. S. Reinhold, A. P. van den Berg and T. K. Yeung

Technical note

Use of a microcomputer for the estimation of X-ray dose received by the fetus 1119
D. McG. Clarkson and S. E. Brennen

Case reports

A case of mitozantrone-associated cardiomyopathy without prior anthracycline therapy 1125
G. R. Pai, N. S. Reed and W. S. J. Ruddell

Asymmetrical pulmonary oedema due to Swyer-James syndrome 1126
E. A. Vanker

Congenital cystic adenomatoid malformation of the lung in a young adult 1128
J. R. Pulpeiro, I. López, T. Soleto, J. C. Ruiz and E. Garcia-Hidalgo

Lymph-node calcification in Lennert's lymphoma 1131
M. P. Williams and G. R. Cherryman

Submucosal gastric haematoma: a case report and review of the literature 1132
S. Elliot and J. Bruce

Detection of mesenteric involvement in sarcoidosis using computed tomography 1135
F. A. Saksouk and M. C. Haddad

The radiological findings in syphilitic proctitis 1137
T. Singcharoen and O.-A. Praisontarangkul

Case of the month

An unusual inguinal swelling 1139
O. Constant and R. A. Mitchell

Short communication

The use of endoscopic ultrasound and laser photocoagulation in the treatment of gastrointestinal tract tumours: early experience 1141
A. C. Steger, S. E. S. Whitecross and N. Hira

Correspondence

Increased potential for tissue discrimination in quantitative magnetic resonance imaging 1142
D. J. Prendergast, D. S. Hickey, J. P. R. Jenkins and I. Isherwood

(continued on inside back cover)

© 1987: The British Institute of Radiology. This publication is copyright under the Berne Convention and the Universal Copyright Convention. All rights reserved, apart from any relaxations permitted under national copyright laws, no part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means without the prior permission of the copyright owners. Permission is not, however, required to copy abstracts of papers or of articles on condition that a full reference to the source is shown. Multiple copying of the contents of the publication without permission is always illegal. Published by The British Institute of Radiology, 36 Portland Place, London W1N 4AT. Printed in Great Britain by The Whitefriars Press Ltd., Tonbridge. ISSN 0007 1285

December 1987

Acc.
22.8.88

Featured in this issue:

Nuclear Reactor Accidents

preparedness and medical consequences

Full proceedings of a one-day seminar held on April 2, 1987.

THE BRITISH JOURNAL OF RADIOLOGY

X-ray diagnosis
Radiotherapy
Nuclear medicine
Ultrasound
Nuclear magnetic resonance
Radiological physics
Radiobiology
Oncology
Hyperthermia
Radiation protection

Published by

The British Journal of Radiology

FOUNDED 1896

The Editorial Committee consists of:

The Editors:

J. T. PATTON, F.R.C.P., F.R.C.R.   N. J. MCNALLY, B.SC., M.SC., PH.D.

The Deputy Editors:

D. G. SHAW, F.R.C.P., F.R.C.R.   C. K. BOMFORD, B.SC., M.PHIL., F.INST.P.

and

The Associate Editors:

J. E. ADAMS, M.B., B.S., M.R.C.P., F.R.C.R.
P. R. BLAKE, M.B., B.S., B.SC., F.R.C.R.
J. A. BULLIMORE, M.B., B.S., M.R.C.S., L.R.C.P., D.M.R.T., F.R.C.R.
P. DAWSON, B.SC., PH.D., M.B., B.S., M.R.C.P., M.INST.P., F.R.C.R.
S. DISCHE, M.D., F.R.C.R.
F. A. DUCK, PH.D., M.I.E.E.E.
A. H. FREEMAN, M.B., B.S., F.R.C.R.
R. M. HARRISON, B.SC., M.SC., PH.D., M.INST.P.
J.W. HOPEWELL, B.SC., PH.D.
W. D. JEANS, M.B., B.S., F.R.C.R.
C. H. JONES, B.SC., PH.D., F.INST.P.
D. M. KING, M.B.B.S., F.R.C.R., D.M.R.D.
H. W. C. LOOSE, D.M.R.D., F.R.C.R.
D. W. PILLING, M.B., CH.B., D.C.H., D.M.R.D., F.R.C.R.
M. J. RAPHAEL, M.A., M.D., F.R.C.P., F.R.C.R., D.M.R.D.
J. R. K. SAVAGE, D.SC.
R. A. SHIELDS, PH.D.
A. R. VALENTINE, M.B., B.S., M.R.C.S., L.R.C.P., F.R.C.R., D.M.R.D.
G. H. WHITEHOUSE, M.B., B.S., F.R.C.P., F.R.C.R., D.M.R.D.
A. G. WILSON, F.R.C.P., F.R.C.R.
E. P. WRAIGHT, M.B., B.CHIR., PH.D., D.M.R.T.

The Associate Editors Overseas are:

P. ARMSTRONG, M.B., B.S., F.R.C.R., D.M.R.D. (North America)
H. K. BADDELEY, M.B., B.S., D.M.R.D., F.R.C.R., M.R.A.C.R. (Australasia)
S. G. A. CHENERY, PH.D., F.C.C.P.M. (North America)
B. J. CREMIN, F.R.C.R., F.R.A.C.R. (South Africa)
R. FOX, D.PHIL. (Australia)
M. TAKAHASHI, M.D. (Japan)
D. M. TAYLOR, D.SC., C.CHEM., F.R.S.C. (Continental Europe)

Managing Editor: LYNN WHITFIELD, B.SC.

Communications should be addressed to the Editors in accordance with the Instructions to Authors which are published in the January issue of the Journal in each year and copies of which may be obtained on application to the Managing Editor.

ADVERTISEMENTS: Communications should be addressed to Advertising Dept., The British Journal of Radiology, 36 Portland Place, London W1N 4AT (01-631 1168).

SUBSCRIPTIONS: All communications should be sent to The British Institute of Radiology, 36 Portland Place, London W1N 4AT, England. Notification of change of address should include an old mailing label and the new address. Claims for missing copies can only be allowed if received within four months of normal delivery date.

ANNUAL SUBSCRIPTION: *1987*, £90 per annum, payable in advance (USA, $159/India, £94). Single copies: £10.00 (available from UK office). *1988*, UK £98, overseas £105.

USA, Canada, Central and South America, Mexico, West Indies: Orders to British Journal of Radiology, P.O. Box #2513, Birmingham, Alabama 35201, USA.

Air-speeded delivery. Second class postage paid at Rahway, N. J. Postmaster: send address corrections to The British Journal of Radiology, c/o Mercury Airfreight International Ltd Inc., 10B Englehard Avenue, Avenel, NJ 07001. British Journal of Radiology (ISSN 0007-1285), monthly.

India: Orders to Universal Subscription Agency Pvt. Ltd., 101-102 Comm. Centre, PB No. 8, Malviya, Nagar Extn., Saket, New Delhi 110017, India (air-speeded delivery).

The British Institute of Radiology

Incorporated by Royal Charter
PATRON: HER MAJESTY THE QUEEN

Founded 1897
36 PORTLAND PLACE, LONDON W1N 4AT
Telephone: 01-580 4085 and 01-580 4189.   Cable Address: "Britology, London W.1."

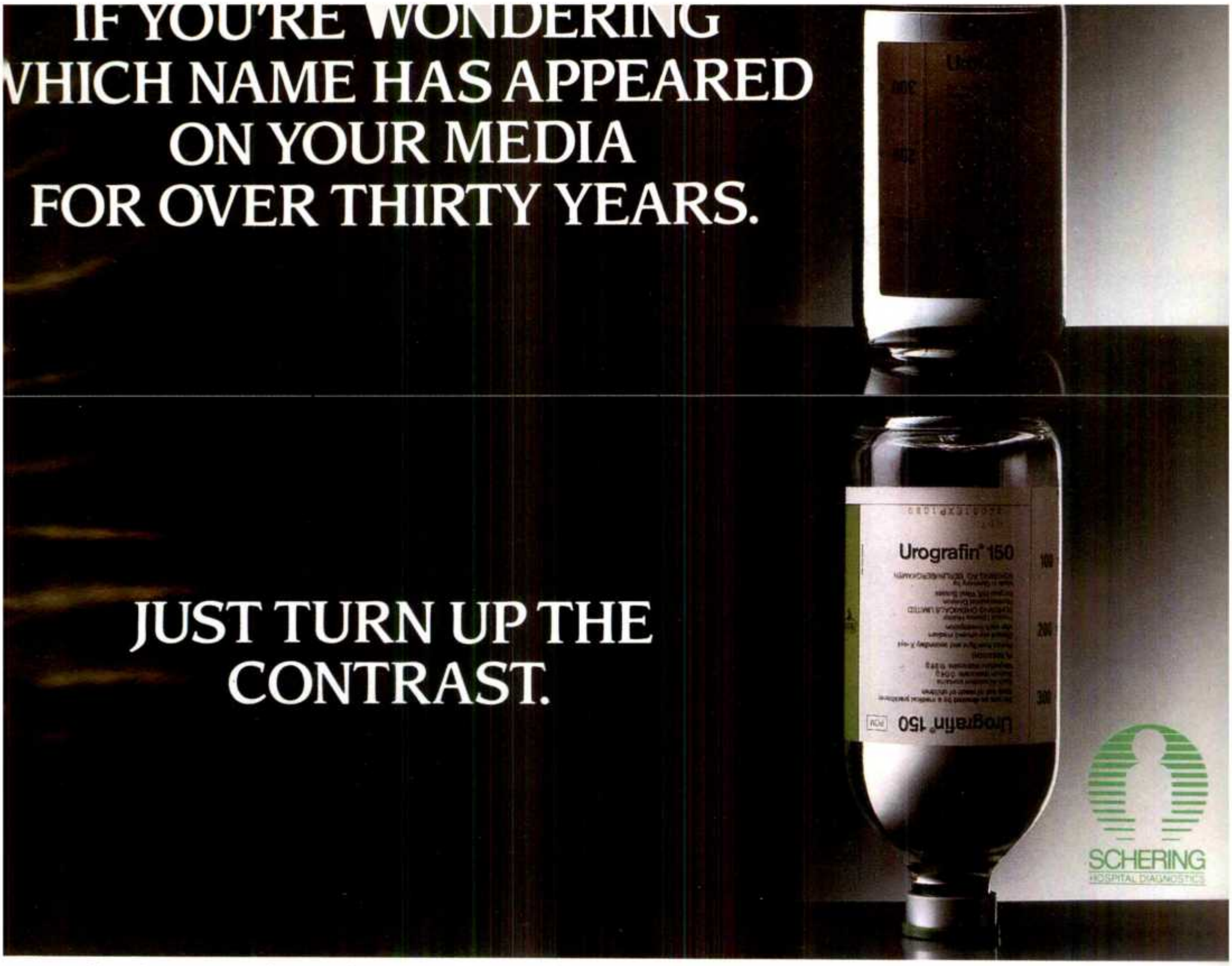
President: G. MOUNTFORD, M.C.A.M., DIP.M., M.B.I.M., D.C.R.

Hon. Secretaries:

M. GOWLAND, M.B., CH.B., F.R.C.R., M.R.C.P. (HON.)
M. J. HARVEY, T.D.C.R., D.M.S.

General Secretary: SUSAN M. JOHNSTONE, B.A.

THE BRITISH INSTITUTE OF RADIOLOGY is an association of persons interested in Radiology and allied subjects. Meetings are held monthly from October until May. Particulars of membership and other information may be obtained on application to the General Secretary at the Institute.



Schering experience in contrast media shows in the carefully selected range of sizes and presentations in which Urografin 150 is supplied. In ampoules or bottles, Urografin 150 is available in the volumes needed for a wide range of radiographic investigations – so that the administration procedure is not interrupted by the distraction of changing bottles. The 500ml size, for example, is specially produced for cystography and videocystometry.

Urografin has been proved by thirty years of experience to give acceptable tolerance, first-class contrast and a low incidence of side-effects at a very modest cost.

In contrast media, experience tells.

Urografin 150

Schering. Clearly a first-class choice.

PRESCRIBING INFORMATION UROGRAFIN 150 – Presentation: An intravenous injection of meglumine diatrizoate 26.1% w/v and sodium diatrizoate 3.9% w/v containing 146mg iodine/ml. **Uses:** X-ray contrast medium for the delineation of the vascular and renal systems. **Dosage and Administration:** Drip-infusion urography 2-4ml/kg body weight up to 250ml, retrograde urography 5-10ml, Cystography up to 500ml. **Contra-indications:** Proven or suspected hypersensitivity to iodine-containing contrast media; manifest thyrotoxicosis; decompensated cardiac insufficiency; hysterosalpingography during pregnancy; acute pelvic inflammation. **Warnings, etc:** Carefully consider need for examination if there is: Severe impairment of hepatic or renal function; cardiac or circulatory insufficiency; cerebral arteriosclerosis; cerebral spasmodic conditions; epilepsy; juvenile-onset or long-standing diabetes; pulmonary emphysema; poor general health; hyperthyroidism; multiple myeloma; a history of allergy. Since safety during pregnancy is not certain, X-ray examinations should be done only if essential. Allergic patients may be hypersensitive. Particular caution in allergic persons who have tolerated a contrast medium without complication; they may have become sensitized. Contrast media and anti-allergic agents must not be mixed. In patients with multiple myeloma, juvenile-onset or long-standing diabetes, polyuria, oliguria, gout or marasmus, and in infants and young children, fluids should not be restricted. Disturbances of water and electrolytes must first be corrected. Premedication with an alpha-blocker is recommended in patients with phaeochromocytoma. Administer Urografin 150 only to recumbent patients, and closely observe for at least 15 minutes. If not already on the X-ray table, those with labile circulations should be brought to the table sitting or lying. Urografin 150 reduces the capacity of the thyroid to take up iodine for a few days, and sometimes up to 6 weeks. Mild symptoms, such as heat and nausea, disappear rapidly when the injection is slowed down or interrupted. Transient pain may occur, in particular during peripheral vascular examinations. Extravasation rarely cause serious tissue reactions. If marked side-effects or suspected allergic reactions occur during injection, and do not disappear, or even worsen, when it is interrupted, stop the investigation. Even minor symptoms such as itching, sneezing, violent yawns, tickling in the throat, hoarseness or coughing may be early signs of a severe reaction. Very rare severe or life-threatening side-effects include hypotensive collapse, circulatory failure, ventricular fibrillation, cardiac arrest, pulmonary oedema, anaphylactic shock or other allergic manifestations, and convulsions or other cerebral symptoms. **Basic NHS price:** 10 x 10ml: **£11.25;** 10 x 20ml: **£18.75;** 1 x 250ml: **£9.21;** 1 x 500ml: **£18.00.**

Product Licence no.: 0053/5041. Product Licence holder: Schering Pharmaceuticals, Division of Schering Health Care Limited, The Brow, Burgess Hill, West Sussex RH15 9NE. Telephone: 04446 6011

elscint

The Image You Can Rely On

Magnetic Resonance Imaging

Computed Tomography

Nuclear Medicine

Ultrasound

Mammography

ELSCINT (G.B.) LTD
Tower Road, Berinsfield, Oxfordshire OX9 8LW
Tel: Oxford (0865) 340900
Fax: Oxford (0865) 341252 Telex: 83341

AUTOMATICALLY PRECISE BIOPSIES

WITH BIOPTY™ – THE NEW, ADVANCED AUTOMATIC BIOPSY SYSTEM

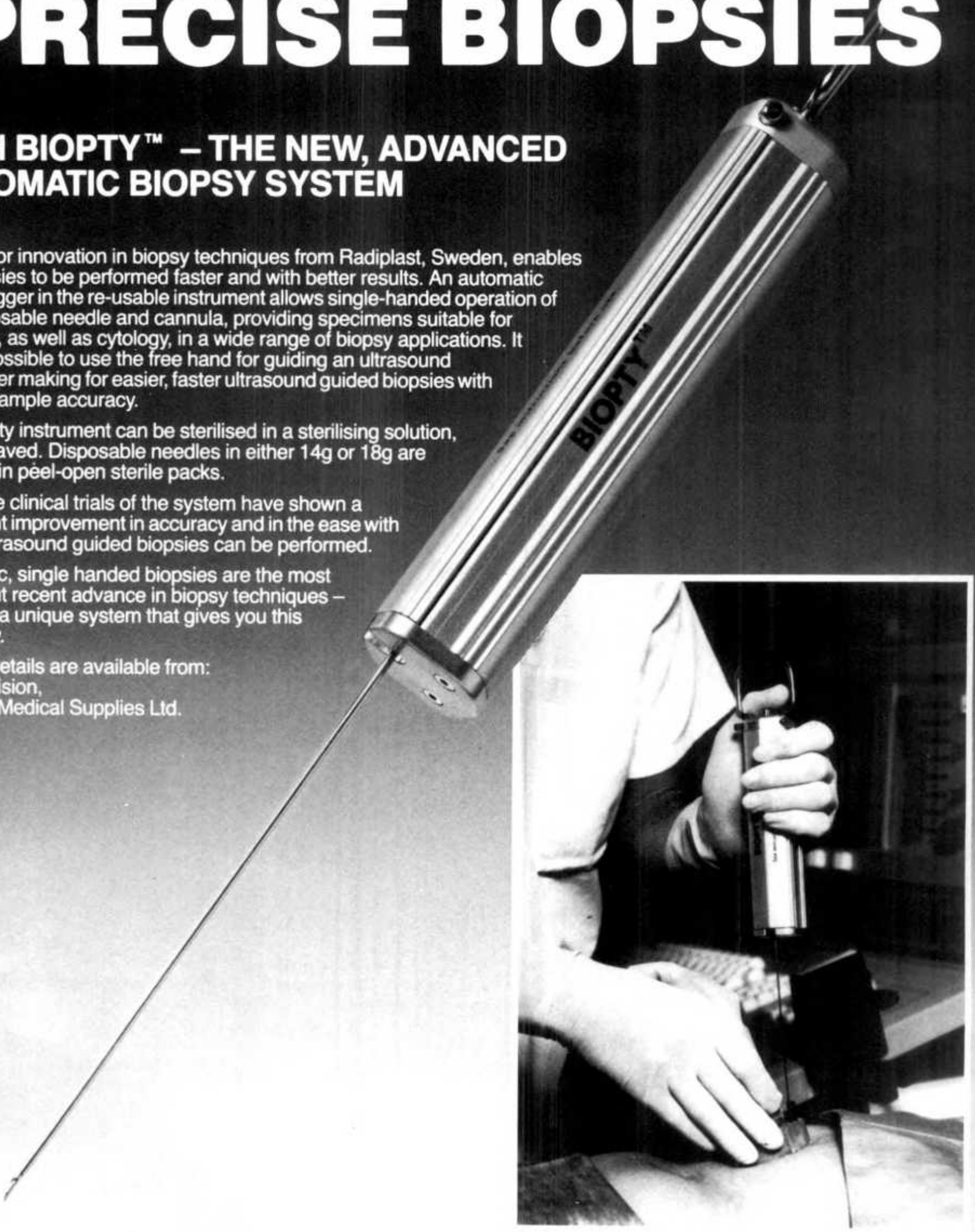
This major innovation in biopsy techniques from Radiplast, Sweden, enables cut-biopsies to be performed faster and with better results. An automatic spring trigger in the re-usable instrument allows single-handed operation of the disposable needle and cannula, providing specimens suitable for histology, as well as cytology, in a wide range of biopsy applications. It is now possible to use the free hand for guiding an ultrasound transducer making for easier, faster ultrasound guided biopsies with greater sample accuracy.

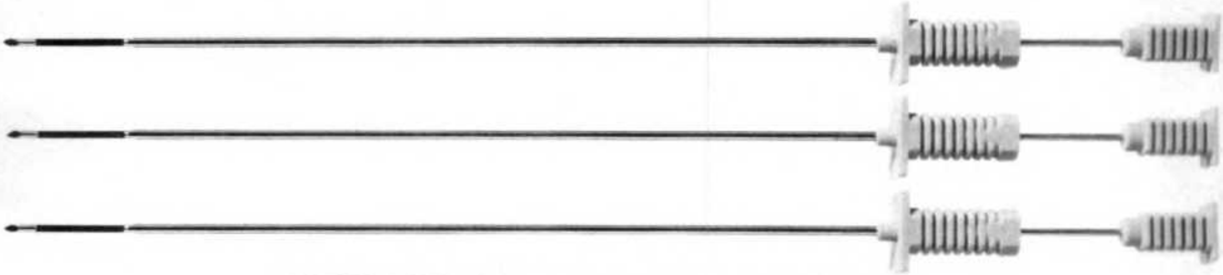
The Biopty instrument can be sterilised in a sterilising solution, or autoclaved. Disposable needles in either 14g or 18g are supplied in peel-open sterile packs.

Extensive clinical trials of the system have shown a significant improvement in accuracy and in the ease with which ultrasound guided biopsies can be performed.

Automatic, single handed biopsies are the most significant recent advance in biopsy techniques – Biopty is a unique system that gives you this capability.

Further details are available from:
X-ray division,
Henleys Medical Supplies Ltd.





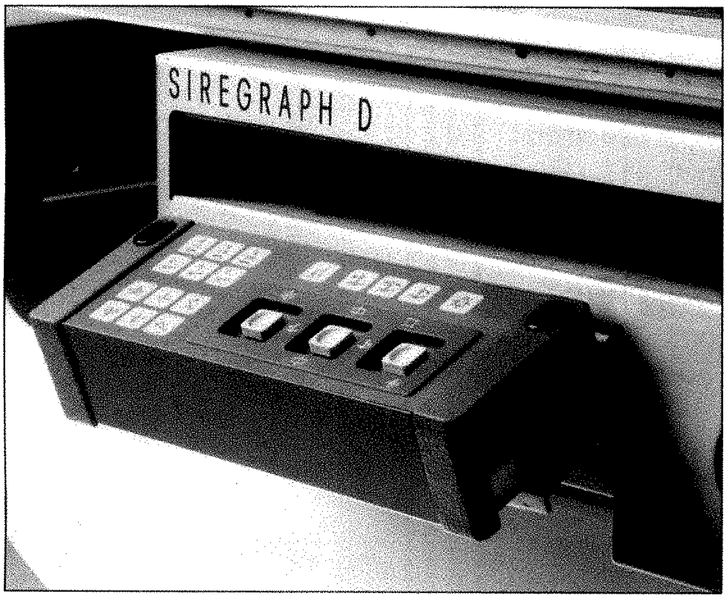
HENLEYS MEDICAL SUPPLIES LTD

SIEMENS

SIREGRAPH D from Siemens –
The remote controlled fluoroscopy table

SIREGRAPH D® represents a new generation of remote controlled tables, setting a new standard in overtable fluoroscopy. Features of the SIREGRAPH D include:

- Advanced and reliable microcomputer technology for the entire control system.
- Silk smooth continuously variable speed control in both acceleration and deceleration.
- Ergonomically designed remote control desk with comfortably placed controls.
- Detachable tableside infra-red control for working near to or remote from the patient.
- Digitally controlled spot film device with flexible multi format cassette programme for maximum film utilization.



SIREGRAPH D is available in a choice of versions with or without lifting base and differing Trendelenburg.

It is the first table of its kind to incorporate fibre-optics for cost effective and reliable connection to the x-ray generator, and utilises microcomputers to control and monitor all functions.

For more information contact:

Siemens Limited
Medical Division
Siemens House
Windmill Road
Sunbury-on-Thames
Middlesex TW16 7HS
Telephone: (0932) 785691
Telex: 8951091

Setting Standards in Remote Control Tables... Siemens

British Journal of Radiology, Supplement 21

Radionuclides in Brachytherapy: Radium and After
Edited by N G Trott

This Report, prepared by a multidisciplinary working party set up by the British Institute of Radiology, reviews the clinical, dosimetric, radiobiological and practical aspects of brachytherapy using γ- and X-rays emitted by both natural and artificial radionuclides.

Radionuclides in Brachytherapy is a comprehensive introduction to the current state of the subject, as well as giving the background to the changes in techniques that have taken place during the last 40 years. Including tables, illustrations, a glossary and an outline of ICRU and BCRU recommendations plus a helpful list of manufacturers and suppliers, this report will be indispensable for anyone involved in theoretical or practical aspects of the radiotherapy, radiobiology or dosimetry involved in this method of treatment.

ISBN: 0905 749 15 4 Price: £12.00
ISSN: 0007 1285 Approximately 70 pp
Publication date: October 1987

Orders to: The Publications Department, The British Institute of Radiology,
36 Portland Place, London W1N 4AT.
Tel: 01 580 4085

BIR PUBLICATIONS FOR USA READERS

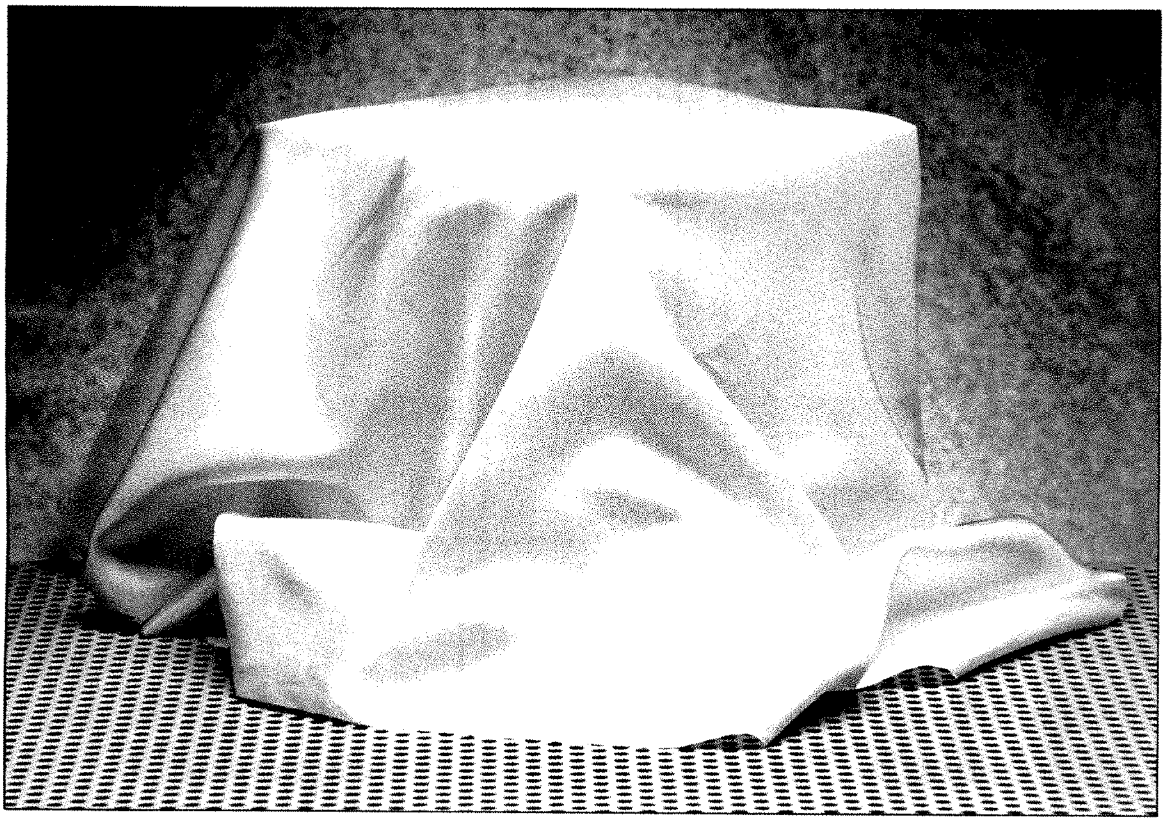
For the convenience of our US readers, selected British Journal of Radiology supplements and textbooks are now available in the US at the following rates (inclusive of postage):

Supplement 19, **Radiation Damage to Skin,** 1986	**$32**
Supplement 18, **Quality Assurance,** 1985	**$29**
Supplement 17, **Central Axis Depth Dose Data for Use in Radiotherapy,** 1983	**$17**
Supplement 16, **Treatment Simulators,** 1981	**$10**
Basic Clinical Ultrasound, (H B Meire and P Farrant) 1982	**$23**

Orders should be directed to:

MEDICAL PHYSICS PUBLISHING CORPORATION
118 N Breese Terrace
Madison
Wisconsin 53705, USA
Tel: (608) 262 9513

UNDER WRAPS-
BUT NOT FOR LONG...



...ANOTHER EXCITING DEVELOPMENT
FROM E-Z-EM® FOR DOUBLE
CONTRAST STUDIES OF THE COLON

e-Z-em®

E-Z-EM is the registered trademark of E-Z-EM Inc, USA.

E-Z-EM Limited
19 Clarendon Road, London N8 0DD
Tel: 01-881 1818

TAKE THE HIGH ROAD
TO SCOTLAND

RADIOLOGY '88

23-25 May 1988 Glasgow

Britain's Open Forum
for all concerned with medical radiology
both diagnostic and therapeutic

STAR SPEAKERS
PROFFERED PAPERS
EXCITING SOCIAL PROGRAMME
MAJOR SCIENTIFIC POSTER EXHIBITION

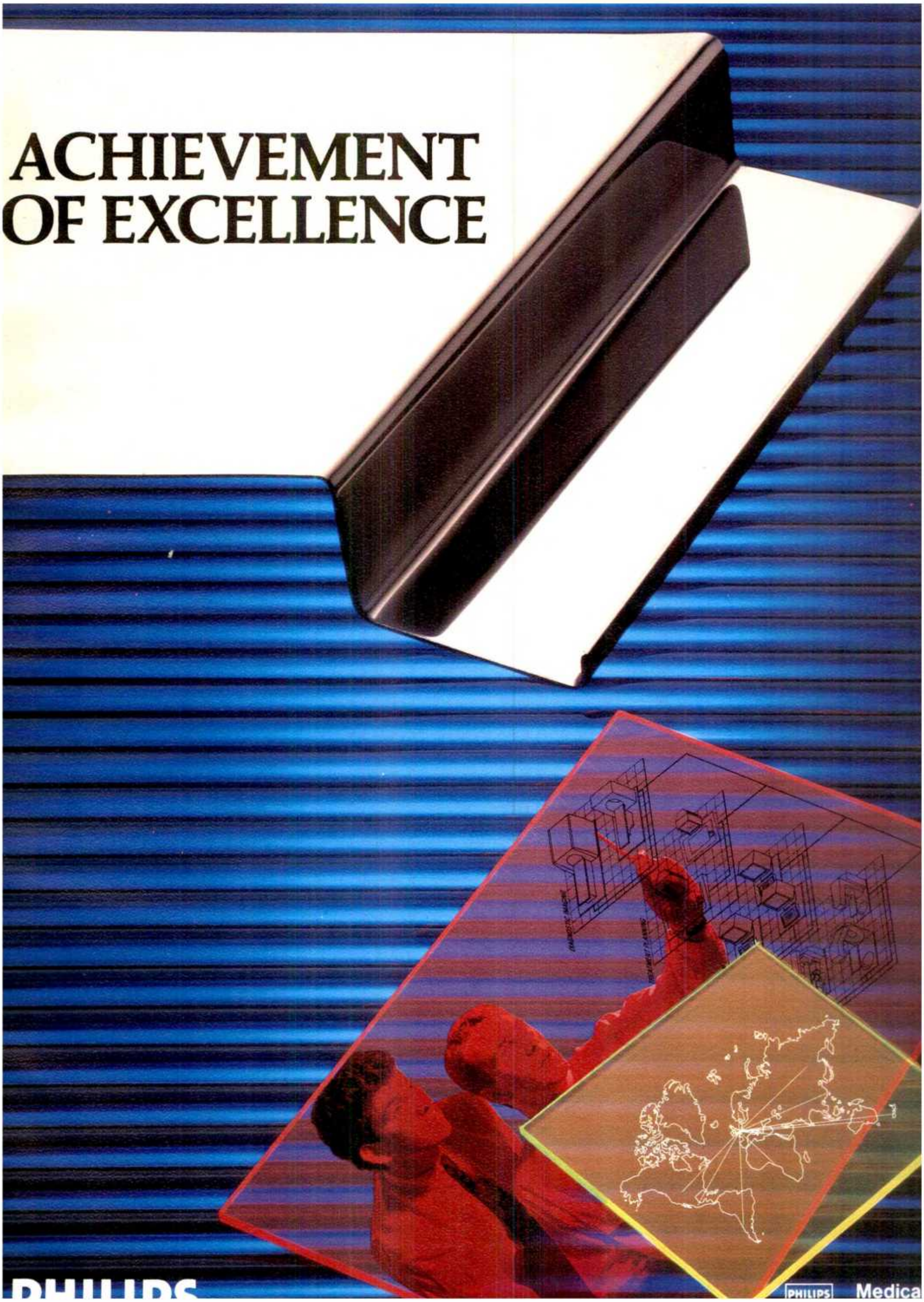
MED X RAY

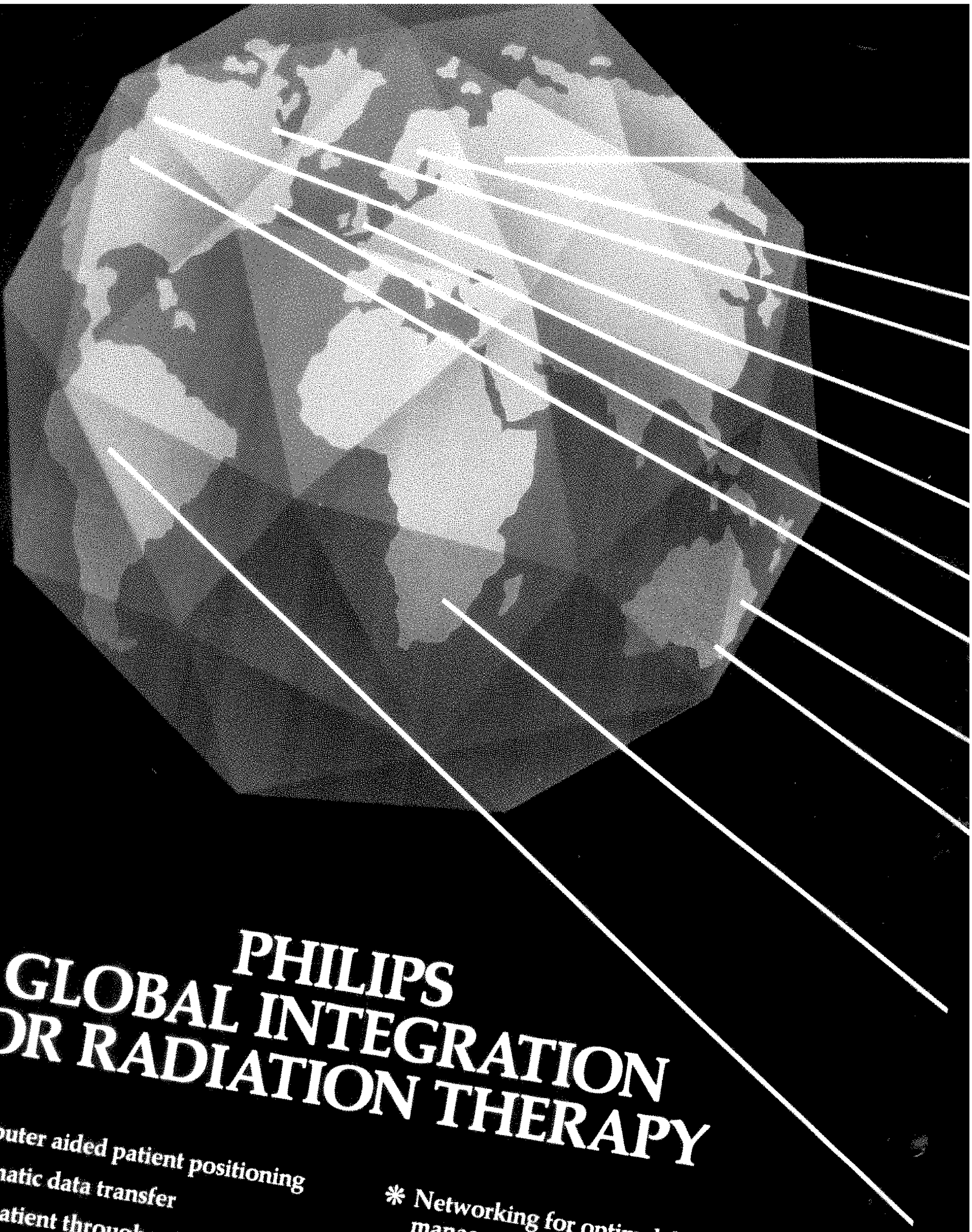
Britain's biggest radiological technical exhibition will span Radiology '88
and the annual conference of the College of Radiographers

RADIOLOGY '88
GLASGOW

Further information from
Conference Office
THE BRITISH INSTITUTE OF RADIOLOGY
36 Portland Place
London W1N 4AT
Telephone: 01-580 4085

RADIOLOGY '88
GLASGOW

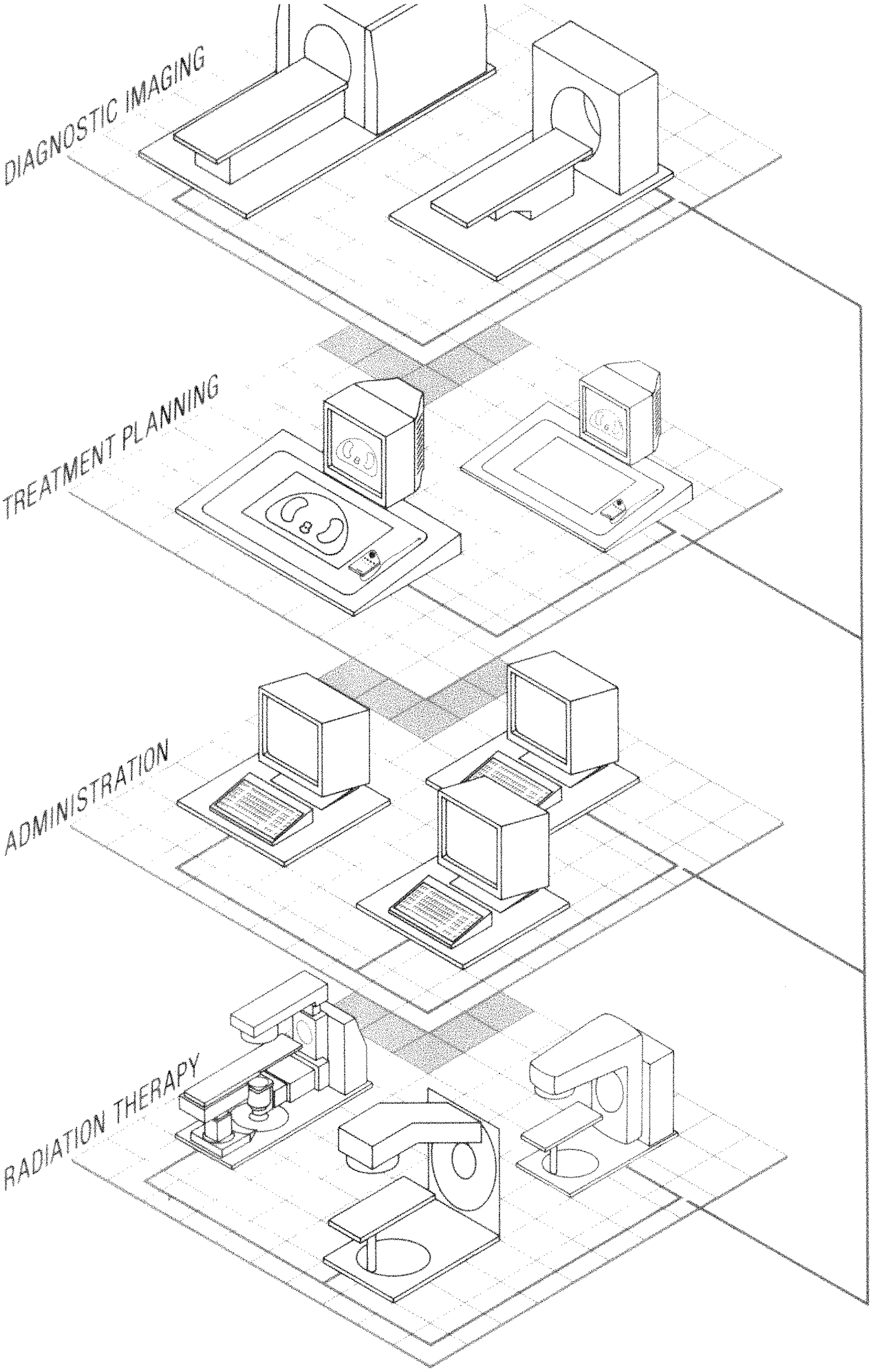

ACHIEVEMENT OF EXCELLENCE
PHILIPS
Medica



PHILIPS
GLOBAL INTEGRATION
FOR RADIATION THERAPY

- Computer aided patient positioning
- Automatic data transfer
- High patient throughput
- Integrated range of compatible systems
- Networking for optimal data management
- Exceptional treatment versatility
- Remote service facility
- Minimum down time

IPS



Contact Philips at one of the addresses shown below
for more information on our full range of equipment for radiation therapy.

Philips Medical Systems, Kelvin House, 63/67 Glenthorne Road, Hammersmith, London W6 0LJ.
Philips Radiotherapy Division, Manor Royal, Crawley, Sussex RH10 2PZ,
Divisions of Philips Electronic & Associated Industries Ltd.

Philips Medical Systems Inc, 710 Bridgeport Avenue, Shelton, Connecticut 06484, United States of America.
N.V. Philips, Medical Systems Division, Eindhoven, The Netherlands.

PHILIPS

PHILIPS **Medical Systems**

HEXABRIX®

SODIUM AND MEGLUMINE IOXAGLATE

A worldwide reputation in the making

Manufactured
by May and Baker Ltd.,
under licence from Guerbet S.A.

M&B May & Baker

Further information available
on request from May and Baker Ltd.,
Dagenham, Essex RM10 7XS

Guerbet

STATE OF KUWAIT
MINISTRY OF PUBLIC HEALTH

CONSULTANT RADIOLOGISTS

Applications are invited from Consultant Diagnostic Radiologists to work in well-equipped hospitals with high standards of health care and modern imaging facilities including Ultrasound, CT and, in the near future, MRI. Unique professional and personal opportunities are offered.

Applicants must hold the FRCR or American Board (Diagnostic Radiology) with experience in CT and/or Ultrasound in a recognised hospital.

Benefits:

- Starting *tax free* monthly salary of 1000–1200 KD (currently 1 KD = £2.2) is offered, depending on experience, plus 150 KD per month as teaching allowance from the Faculty of Medicine, Kuwait University. There are no exchange/currency restrictions in Kuwait.
- Fully furnished, air-conditioned accommodation.
- Air tickets for appointee, wife and 3 dependent children on joining duty, termination of contract and for annual leave.
- Annual leave is 30 days plus 15 days special X-ray leave.
- Ministry may fund attendance of one conference abroad each year if a scientific paper is to be presented.

Applications together with full CV, copies of qualifications and experience certificates, plus names and addresses of two referees should be made to:

**Dr Nail Al-Naqeeb, FRCS Ed.
Undersecretary
Ministry of Public Health
P.O. Box –5
13001 KUWAIT**

British Journal of Radiology Supplement 19

Radiation Damage to Skin

Fundamentals and Practical Aspects

Proceedings of a Workshop held at Saclay, France, on October 9–11, 1985, organised by the Commission of the European Communities and the Commissariat à l'Energie Atomique de Protection et de Sûreté Nucléaire, Fontenay-aux-Roses, France.

Skin and underlying tissues are frequently critical structures in radiological protection. Over exposure to ionising radiation can cause serious long-term suffering and disability

Despite their practical importance, the dose-effect relationships, the pathophysiological mechanisms and the influence of the degree to which different tissues are involved are still poorly understood.

This Workshop and Proceedings bring together those at the forefront of research in these areas from all over the world They review the present state of knowledge and attempt to identify specific problem areas which may lead to recommendations for the improvement of radiological protection and for the better management of radiation accidents.

Radiation Damage to Skin is, therefore, a vital reference work for everyone working in radiation protection and dosimetry

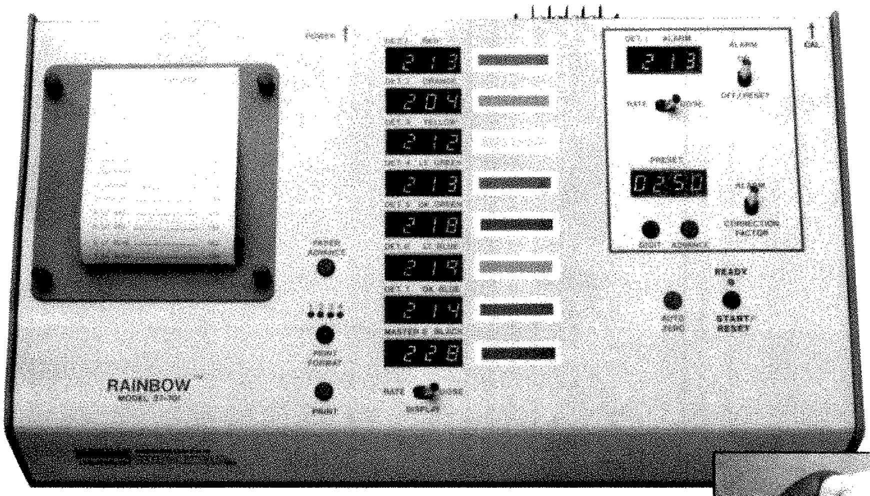
Price £18 00 including postage and packing. About 200 pp.; illustrated.

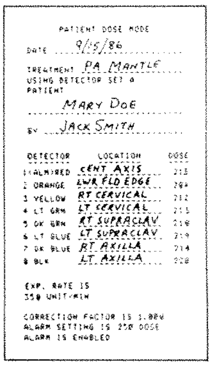
ISBN 0–905749–13–8
ISSN 0007–1285

Orders to: The Publications Department, The British Institute of Radiology, 36 Portland Place, London W1N 3DG. Tel: 01-580 4085.

Diode Dosimetry Systems

Patient Dose Verification and QA Beam Analyzer





PATIENT DOSE MODE
DATE 9/15/86
TREATMENT PA MANTLE
USING DETECTOR SET A
PATIENT
MARY DOE
BY JACK SMITH

DETECTOR	LOCATION	DOSE
1 ALMHRED	CENT AXIS	213
2 ORANGE	LWR FLD EDGE	204
3 YELLOW	RT CERVICAL	212
4 LT GRN	LT CERVICAL	213
5 DK GRN	RT SUPRACLAV	218
6 LT BLUE	LT SUPRACLAV	219
7 DK BLUE	RT AXILLA	214
8 BLK	LT AXILLA	228

EXP. RATE IS
350 UNIT/MIN

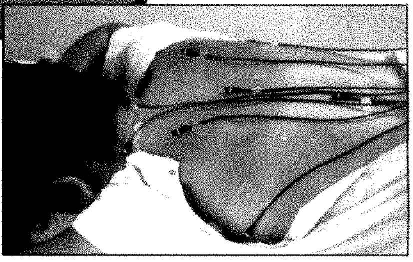
CORRECTION FACTOR IS 1.00N
ALARM SETTING IS 250 DOSE
ALARM IS ENABLED

PRINTED OUTPUT FOR PATIENT CHART

8 DISPLAYS

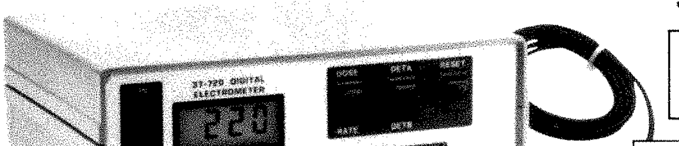
RAINBOW™

- Instantaneous Display of Treatment Dose
- Verifies Treatment Plans
- QA Checks of Beam Symmetry, Flatness and Energy

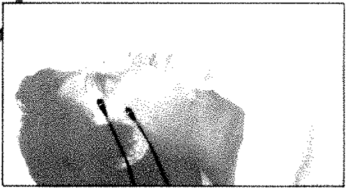


8 DETECTORS

Instant Data on Exposure to Sensitive Organs During Treatment



DUAL DIODE DOSIMETRY SYSTEM



- Dual Channel Electrometer
- Rapid Checks of Equipment Output

For more details on Diode Dosimetry Systems, request Bulletin 3712-14

NUCLEAR ASSOCIATES

VICTOREEN

A Division of VICTOREEN, INC.
100 VOICE ROAD
CARLE PLACE, NY 11514-1593 U.S.A.
(516) 741-6360
A Subsidiary of Sheller-Globe SG

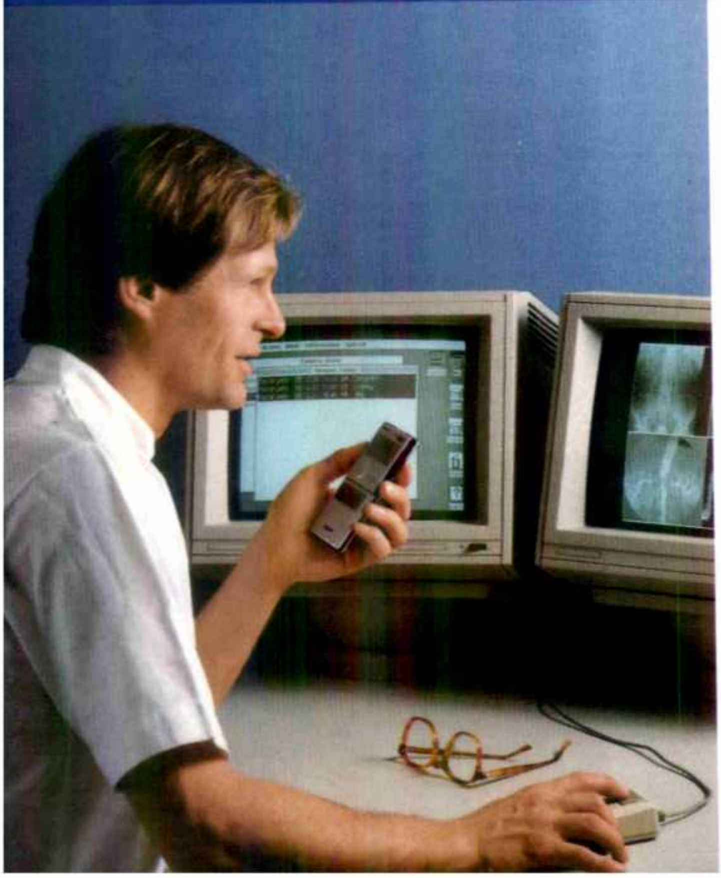
™ Victoreen, Inc.

If the increase of patient throughput and the growth of image production threatens the quality of your x-ray department, you'll want to get in on MARCOM.

It's Philips' Medical Archiving and Communication system, which will not only save you space by storing all images on digital optical disks, but at the same time will give you a level of archival organisation and efficiency that will simply never be possible with conventional film.

But that's not all, MARCOM also gives you image compatibility, which means that you can use high resolution viewing stations to compare any images you want at any time.

If you're into digital, you'll want to get in on MARCOM.



And, MARCOM can interface with administrative and accounting departments.

So, if you like what you can do with digital images, you'll really like what MARCOM can do for you. Because MARCOM's modular concept allows you to build up an all-digital capability step-by-step, you can determine your needs as you go and ultimately obtain the best configuration for your institution.

Philips Medical Systems
Kelvin House
63-75 Glenthorne Road,
Hammersmith,
LONDON, W 6 OLJ

PHILIPS Medical Systems

PHILIPS

1987, *The British Journal of Radiology*, *60*, 1147–1158

VOLUME 60 NUMBER 720 DECEMBER 1987

The British Journal of Radiology

The Chernobyl reactor accident: the impact on the United Kingdom *†

By F. A. Fry

National Radiological Protection Board, Chilton, Oxon

(Received April 1987 and in revised form June 1987)

I am deeply honoured to be asked to present the Mayneord Lecture at Radiology '87 and I would like to thank the President and the Council for the invitation. I received this invitation at a time when I, with many of my colleagues, was still heavily involved in evaluating the effect of the Chernobyl reactor accident in the United Kingdom and I felt able to accept on their behalf since this provides me with an opportunity to acknowledge the contributions that so many of them have made in the last year.

My colleagues and I will remember 1986 as the year of the reactor accident—the accident that many had thought would not occur, but for which eventuality we had nevertheless prepared with emergency plans and practices. The accident was indeed a tragedy. People have already died and many more may die of malignancies in later years. People in the Soviet Ukraine and Byelorussia have suffered socially and economically. Radionuclides have been deposited throughout the northern hemisphere, causing international concern and some confusion. It is imperative that we learn from this experience.

In early studies of the potential hazard of man-made radionuclides released into the environment, Professor Mayneord made the point that "the first necessity is to obtain accurate, detailed information on the nature and amounts of radionuclides both natural and artificial occurring in the environment and the human body" (Mayneord et al, 1958). Nearly 30 years later, we have spent almost a whole year doing just that on a scale he would not have envisaged.

In this lecture, I intend to concentrate upon the impact of the accident within the UK: the deposition and transfer of radionuclides, doses to the population, and lessons for the future. Firstly, however, it may be useful to describe the existing arrangements for monitoring radionuclides in the environment and for dealing with emergencies.

RADIOACTIVITY IN THE ENVIRONMENT

We live in a naturally radioactive environment. Radiation reaches the earth from outer space, the earth itself is radioactive and naturally-occurring radionuclides are present in the air we breathe, in the food we eat and in our own bodies. Everyone is exposed to natural radiation and for most people it is the largest source of exposure. In the last 30 years or so, man's actions have made an additional contribution to the global inventory of activity, a contribution that may be small in relation to total activity but one that is nevertheless readily discernible since, in general, the radionuclides produced are different from those occurring naturally. The atmospheric testing of nuclear weapons made a significant input during the mid-1950s and early 1960s until the partial test-ban treaty in 1963. It is salutary to remind ourselves that atmospheric testing produced almost 10^{21} Bq of iodine 131, 10^{18} Bq of caesium 137 and about half that quantity of strontium 90 (United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1982).

Radioactive materials may be discharged from nuclear installations and, to a lesser extent, from other industrial premises and from medical and research institutes. All discharges must be authorised and monitoring programmes are prescribed for significant discharges. Accidental releases of radionuclides may also occur and, as we saw last year, a severe accident at a nuclear power station can lead to widespread contamination of the environment.

Once radioactive materials have entered our environment, they are subject to all the normal processes of dispersion and transfer through ecosystems in a manner that depends upon their physical, chemical and biological properties. No matter how complex the pathway by which they may eventually reach man, the actual mechanisms of human exposure are few: external irradiation from airborne material, inhalation of airborne material, external irradiation from radionuclides deposited on the ground, and ingestion of activity in food or water. In order to evaluate doses to individuals or to population groups, measurements must be related to these mechanisms of exposure. Thus, we measure external dose rates and also activity concentrations in air, water and foods. We need to know or estimate values of other parameters such as occupancy factors for external irradiation and intake rates for internal exposure. We also need models that describe the uptake and metabolism of radionuclides

---

*© Crown copyright 1987.

†The 1987 Mayneord lecture delivered at "Radiology '87" in Southampton on Thursday, April 2.

and the irradiation of tissues. In some circumstances we can check our calculations by making direct measurements of radionuclides in persons.

Routine Monitoring Programmes

Routine surveillance of widespread radionuclides in the UK is conducted by both the National Radiological Protection Board (NRPB) and the Atomic Energy Authority's Harwell Laboratory. Air is sampled at seven locations and rainfall is collected at 10 locations. The results are combined and reports are issued annually (Cambray et al, 1985; Smith et al, 1985). In the case of the Harwell Laboratory, this is only part of a worldwide sampling programme commenced in 1954 and aimed primarily at an understanding of the behaviour of debris from weapons testing. Taken together, these sampling locations provide reasonable geographical cover across the UK and permit estimation of the dose to the population from widespread radionuclides In general, the only radionuclides detected are those that occur naturally and those resulting from weapons testing, but the programme is sensitive to other sources. The radionuclides of interest in the long term are strontium 90, caesium 137 and plutonium isotopes, although shorter-lived radionuclides such as iodine 131 are important soon after a weapons test or an accidental release

The NRPB also measures radionuclides in milk as a guide to activity in diet. The sampling scheme for the UK was devised by the Agricultural Research Council's Letcombe Laboratory which originated this programme in 1958 (ARC, 1961). Samples of milk are obtained monthly from over 70 depots that together handle a significant fraction of the total milk produced in the UK. The depots were selected to ensure representative sampling with due regard to location and size. Aliquots are taken in proportion to the quantity of milk handled to give representative samples for England, Wales, Scotland and Northern Ireland. In 1981–82, the scheme was extended to include the Channel Isles and the Isle of Man. The radionuclides normally of interest are strontium 90 and caesium 137, although additional samples are taken for analysis of iodine 131 shortly after weapons tests in the atmosphere or nuclear accidents.

All nuclear installations undertake routine environmental monitoring, the sampling and measurement programme at each site depending upon the nature of the operations and the actual or potential releases. The programme may include direct measurements of external dose rate, activity in air, in water and in foods or other environmental media. Independent monitoring is carried out by the authorising departments, the Department of the Environment (DoE) and the Ministry of Agriculture, Fisheries and Food (MAFF), both around nuclear sites and further afield.

Emergency Planning

All nuclear sites must have an emergency plan which must be exercised regularly. In the event of a serious accident, the national emergency plan would come into effect. The operator of the affected site would set up an Operational Support Centre and the Department of Energy would open a Nuclear Emergency Briefing Room in London. Representatives of organisations such as DoE, MAFF and NRPB would be present at both to advise on any necessary actions. The operator of the site is responsible for monitoring in the vicinity of the site where countermeasures might be required. On a national scale, the NRPB would undertake and co-ordinate thorough monitoring of the environment to provide reassurance to the public that all areas of significant contamination had been identified, and to accumulate data for subsequent evaluation of dose to the population as a whole. This national monitoring would draw upon measurements provided by the monitoring networks described above, supplemented by measurements of dose rate obtained by mobile teams.

The NRPB has recommended criteria for limiting doses to the public in the event of accidental exposure. The countermeasures which may be effective in the early stages of an accident are evacuation, sheltering in houses and distribution of iodine tablets. Each of these involves different risks and costs. The NRPB has therefore recommended ranges of dose in respect of the introduction of each countermeasure (NRPB, 1981). As shown in Table I, for each action there is a lower level at which consideration of intervention should begin. If predicted doses exceed the lower level, implementation

TABLE I

Recommended emergency reference levels

Countermeasure	Dose equivalent level (mSv) Lower			Upper		
	Whole body	Thyroid, lung or other single organs	Skin	Whole body	Thyroid, lung or other single organs	Skin
Evacuation	100	300	1000	500	1500	5000
Sheltering	5	50	50	25	250	250
Distribution of stable iodine tablets	—	50	—	—	250	—

of the countermeasure is desirable but not essential. Above the higher level, the countermeasure should be introduced whatever the circumstances. As regards contamination of foodstuffs, there is likely to be more time for taking decisions on control than is the case for the other countermeasures. In general, it has been considered that there is little penalty in withholding distribution of fresh milk or other foods and action should be taken to limit doses to 5 mSv to the whole body or 50 mSv to an organ. To aid decisions, we have calculated derived quantities, that is activity concentrations in foods that would lead to these doses, for a number of radionuclides and for foods such as milk, green vegetables and fruit for which there could be a rapid transfer of activity to man (Linsley et al, 1986). For most other foods a significant time will elapse before the radionuclides reach man and there will be sufficient time to perform an evaluation of the specific circumstances.

The Chernobyl reactor accident did not constitute an emergency for the UK and the emergency plan was not formally invoked. Nevertheless, some elements of this plan were brought into operation.

THE ACCIDENT AND THE SPREAD OF ACTIVITY

The circumstances of the severe accident that occurred at the Chernobyl nuclear power station in the western Ukraine on Saturday April 26, 1986 at 01.23 local time, releasing substantial quantities of radionuclides to the atmosphere, are now well known (USSR, State Commission on the Use of Atomic Energy, 1986). Most of the activity was released over a period of about 10 days with two peaks in release rate, on April 26 and on May 5, but much lower releases may have persisted until September when it was announced that the reactor was effectively sealed. Almost all the inert gases were released, 10–20% of the isotopes of the more volatile elements such as iodine and caesium and a few per cent of the other fission and activation products and the actinides The releases of the radionuclides of potential radiological significance are shown in Table II.

It has been suggested that as much as half the initial release was borne with the explosion to a height of 3 km or more through the inversion layer and then transported eastwards (Beardsley, 1986). This would explain the early detection of Chernobyl-derived activity in Japan (Aoyama et al, 1986). Although the heat of the fire caused considerable plume rise, the rest of the initial release was injected at lower altitude and its movement was determined by surface winds. The behaviour of the contaminated air mass that spread over western Europe has been described by others (ApSimon & Wilson, 1986; Smith & Clark, 1986). Initially, contaminated air was blown towards Scandinavia, and our first indications of elevated dose rates and concentrations of activity in air were obtained from colleagues in Sweden. The air mass remained stagnant for the next 2 days and then drifted southwards over Poland and across Germany, eventually reaching the UK on May 2. By this time, the contamination had reached most of Europe and we were receiving reports of elevated external dose rates and activity concentrations from many countries. Later releases from the reactor were transported eastwards, although some of this material may have subsequently turned north, passing across Germany to the North Sea.

TABLE II

CHERNOBYL RELEASES

Radionuclide	Activity, 10^{15} Bq	
	1st day	10 days
^{131}I	170	440
^{134}Cs	5	25
^{137}Cs	10	50
^{90}Sr	0.5	9
^{239}Pu, ^{240}Pu	0.1	0.7

Laboratories in the south of England observed increased dose rates and detected activity in airborne dust on Friday, May 2, but there is evidence to suggest that some activity had arrived earlier. Enterprising staff at a London hospital made use of an automatic counter to detect the first arrival of Chernobyl activity (Institute of Physical Sciences in Medicine (IPSM), 1986). They recorded an increase in counting rate attributable to iodine 131 at 11.00 am on Thursday, May 1. The absence of the other radionuclides could perhaps be due to the removal of particulate material by the hospital filtration system but an alternative explanation could be that non-particulate iodine 131 arrived in advance of the main cloud of activity. This may account for the early appearance of iodine 131 in milk, discussed below.

The contaminated air mass moved across the UK from the south-east during May 2, a generally dry and sunny day. Rain and thunderstorms followed during the weekend. Rainfall was particularly heavy during the passage of the cloud of activity over north Wales, Cumbria and south-west Scotland, leading to elevated deposition of radionuclides in these areas.

Although this event did not represent an emergency for the UK, it was appropriate to put some parts of the national emergency plan into effect. The organisations performing environmental monitoring intensified their sampling and analysis programmes. The agricultural departments mounted massive monitoring programmes for foods and DoE arranged for sampling and analysis of water supplies. All these results were sent to the NRPB for collation and analysis. Frequent summaries were made available to DoE and subsequently published. In the following 3 weeks, we received approximately 20 000 items of data, all of which were published by Her Majesty's Stationery Office (HMSO) (DoE, 1986). Agricultural monitoring was intensive and prolonged; indeed it is still in progress and more recent results have been published separately (MAFF, 1987). The following analysis of the behaviour of the activity and evaluation of doses draws upon these and other published data, but there is inevitably considerable emphasis on work performed at our own laboratories at Chilton and Glasgow.

ENVIRONMENTAL MEASUREMENTS

Airborne activity

Airborne activity from Chernobyl was first detected at Chilton on the morning of May 2. The gamma-ray spectrum of activity collected on an air filter revealed a complex mixture of fission and activation products, the predominant activities being due to molybdenum 99 and its decay product technetium 99m, ruthenium 103 and 106, iodine 131, tellurium 132 and its decay product iodine 132, caesium 134, 136 and 137, and barium 140 and its decay product lanthanum 140. Size-selective air sampling at one site in southern England indicated that the aerosol collected at the time of maximum concentration had an approximately log-normal size distribution with an activity median aerodynamic diameter (AMAD) of 2–4 μm and a geometric standard deviation of about 2 (Nair & Darley, 1986). Measurements in Switzerland have shown a somewhat smaller size distribution, with AMADs of about 0.9 μm for ruthenium 103, tellurium 132 and caesium 137, very similar to that of the ambient aerosol (Jost et al, 1986). Most iodine 131 in particulate form was associated with sizes less than 0.5 μm. The discrepancy may be due to the different nature of both particulate and non-particulate fractions of the materials released at the various stages of the accident and their subsequent behaviour.

Measurements of iodine 131 both in the UK (Hancock & Woollam, 1986; Cambray et al, 1987) and elsewhere (Devell et al, 1986) have shown that the total concentration was four to five times higher than that collected on filters since much of the iodine 131 was present in a form that was either not attached to particles or readily desorbed from particles. The concentrations of the actinides, that is isotopes of plutonium, americium and curium, were very low.

At Chilton, the concentration of caesium 137 in air reached a maximum during the afternoon of May 2, declined to about one-hundredth of the maximum value the following morning and then decreased by a further factor of 10 during the next few days. A slight increase was observed during May 7, but this subsidiary peak was only about one-hundredth of the level observed on May 2. A similar increase was reported in Paris, about 2 days earlier (Thomas & Martin, 1986) and may be evidence for some local recirculation of the much depleted air mass. Slightly elevated levels in the latter half of May were probably due to debris that had circled the earth in an easterly direction. Subsequently, during June and July, concentrations decreased with a half-life of approximately 7 days, but since then they have remained fairly constant at around 10 μBq m^{-3}, compared with the pre-Chernobyl level of about 1 μBq m^{-3}.

TABLE III

INTEGRATED ACTIVITY CONCENTRATION (BQ H M^{-3}) MAY 1986

Radionuclide	Chilton	Glasgow
^{99}Mo	8	3
^{103}Ru	34	22
^{106}Ru	13	—
^{131}I*	44	33
^{132}Te–^{132}I	54	71
^{134}Cs	9	11
^{136}Cs	2	—
^{137}Cs	21	21
^{140}Ba, ^{140}La	7	9
^{239}Pu, ^{240}Pu	3×10^{-4}	—

*Particulate component only.

Peak concentrations in the north of the UK were attained somewhat later than in the south. The highest concentration recorded at Glasgow was attained on the afternoon of May 3. Nevertheless, the integrated concentrations of all radionuclides during May were fairly similar at these two locations (Table III). Differences in these values obtained at other sampling sites are due to the movement of the contaminated air mass which seemed to avoid the south-west of the country. Higher than average integrated concentrations were observed in north-west England and south-west Scotland, presumably due to the persistence of the contaminated air mass over this region of the country. A similarly high value observed at one location on the east coast is an anomaly, which may suggest that this station sampled a part of the air mass which did not reach the rest of the country, perhaps part of the air mass from central Europe that was funnelled up northwards over the North Sea (ApSimon et al, 1987).

External irradiation

External irradiation results from immersion in the cloud of airborne activity and from radioactive material deposited onto surfaces. The external exposure was measured directly at a number of locations (DoE, 1986). External exposure from the passage of the contaminated air mass was similar across the country and differences between external exposure rates in various locations resulted from the elevated deposition of radionuclides in areas of high rainfall. In the dry areas of southern England the peak dose rate represented an increase of only 10–30% over normal levels due to terrestrial sources of natural radiation of 50–80 nSv h^{-1}, whereas in regions of high deposition the peak dose rate more than doubled; at Glasgow, for example, the peak represented an increase of 240 nSv h^{-1} above a normal dose rate of 120 nSv h^{-1}. Since most of the initial irradiation was due to short-lived radionuclides, the dose rate decreased quickly with time and within about 10 days it was indistinguishable from normal values. Dose rates at later times are therefore computed from the measured deposition.

TABLE IV

DRY DEPOSITION ONTO HERBAGE (M S^{-1})

Radionuclide	Chilton	Berkshire	Guernsey
^{103}Ru	4×10^{-4}	2×10^{-4}	—
^{131}I	8×10^{-4}	3×10^{-4}	1×10^{-2}
^{132}Te	8×10^{-4}	2×10^{-4}	—
^{137}Cs	4×10^{-4}	3×10^{-4}	1×10^{-4}

TABLE V

WASHOUT RATIOS OBSERVED AT GLASGOW

Radionuclide	May 3, 1986	May 4–5, 1986
^{103}Ru	3×10^3	5×10^3
^{131}I	3×10^3	3×10^3
^{132}Te	6×10^3	6×10^3
^{134}Cs	6×10^3	6×10^3
^{137}Cs	5×10^3	5×10^3
^{140}Ba	5×10^3	3×10^3

Deposition

Airborne radionuclides are deposited onto surfaces by a number of processes. In the absence of rainfall, dry deposition is characterised by the parameter deposition velocity, defined as the quotient of total deposition per unit area to the integrated concentration in air. The value of the parameter varies with the nature of both the airborne activity and the surface. For deposition of aerosols of about 1 μm AMAD onto grass, the deposition velocity is generally assumed to lie in the range 10^{-4} to 10^{-3} m s^{-1} (Sehmel, 1980). The value for elemental iodine is perhaps a factor of 20 higher, whereas that for organic iodine is a factor of 10 to 100 less. Observed deposition velocities to grass are shown in Table IV. The values for ruthenium 103, tellurium 132 and caesium 137 lie in the expected range. The values for iodine 131 are more variable, perhaps due to variability in gaseous and particulate fractions. Total deposition of a radionuclide is conventionally taken to be a factor of four times higher than its deposition onto grass, and this can be measured independently by determining activity in root mat and soil after weathering of activity from the grass.

Removal of activity from the atmosphere by rain is a more efficient process than dry deposition. Two main mechanisms are involved: the term washout refers to activity removed by interaction with raindrops falling through the contaminated air mass whereas rainout is used to describe the incorporation of activity into growing rain drops within the rain cloud. However, because of the difficulty of distinguishing between these processes, the effect is usually described by one parameter called, for convenience, the washout ratio. This is defined as the ratio of the concentration of the radionuclide in surface-level precipitation to its concentration in surface-level air. The washout ratio will vary with particle size and rainfall intensity. It is normally used to describe long-term average conditions. For small particles, the washout ratio, expressed on a mass basis, lies typically in the range 10^2–10^3 (McMahon & Denison, 1979). In addition, other meteorological conditions, such as mist, fog or low-lying cloud on hills, may lead to increased deposition.

Washout ratios obtained at Glasgow, a location which experienced heavy rainfall during the passage of the Chernobyl activity, are given in Table V. They are surprisingly consistent, although somewhat larger than expected. However, it is not unreasonable to find quite large differences when washout ratios are computed for short-term rain storms.

Total deposition can be calculated from the activity collected by deposition collectors or by measurement of activity in soil. Where we have both sets of data, the results are comparable. These data, together with total deposition inferred from deposition onto grass, can be used to obtain the pattern of deposition across the country. Deposition of iodine 131 ranged from about 10^3 Bq m^{-2} in dry regions, to about 10^4 Bq m^{-2} in regions of heavy rainfall. Values for caesium 137 are typically a few tens of Bq m^{-2} for dry areas and a few thousand Bq m^{-2} for wet regions. In the dry areas, the Chernobyl accident has made an insignificant addition to the cumulative caesium 137 from weapons testing whereas in areas of high rainfall the Chernobyl deposition was comparable with existing levels. The initial caesium 134 deposit was about half of the Chernobyl-derived caesium 137.

Transfer to milk

Following deposition, activity may be transferred to man via food chains, the radionuclides of importance being iodine 131, caesium 134 and caesium 137. Milk is the foodstuff of initial concern because of the rapid transfer of activity to milk, the large area grazed by a cow and the importance of milk in the diet of infants and young children. Following news of the accident, MAFF commenced daily sampling at a few farms and dairies in south-east England, but no activity was detected until May 3. Concentrations of all three radionuclides in milk peaked rapidly, maximum values being observed within a few days of the initial deposit. Typical peak concentrations for areas of low and high deposition are shown in Table VI together with the

TABLE VI

TYPICAL PEAK ACTIVITY CONCENTRATIONS IN MILK AND INTERVENTION CRITERIA (BQ L^{-1})

Radionuclide	Dry areas	Wet areas	Intervention criterion
^{90}Sr	0.1	0.7	1200
^{131}I	50	200	2000
^{134}Cs	7	100	3100
^{137}Cs	15	200	3600

COLLEGE OF MEDICI LIBRARY

intervention criterion for each radionuclide considered separately. Even with all three radionuclides considered together, the activity did not approach the level at which we would have recommended action.

Strontium 90 poses a potential difficulty in that normal methods of analysis are time-consuming and results are typically available only 3 weeks after sampling. Fortunately, a rapid method was employed by one laboratory that showed that strontium 90 concentrations were very low; this was subsequently confirmed by other laboratories employing their standard methods. The strontium 90 concentration shown in Table VI for the dry areas is no different from that expected from weapons testing. For the wet regions, the Chernobyl contribution to strontium 90 in milk is 0.6 Bq l^{-1} implying a caesium 137 to strontium 90 ratio of about 300 for the Chernobyl activity in the foodchain. The ratio of the intervention criteria is about three and on this basis we were able to dismiss the strontium 90 as a negligible radiological problem.

We have taken advantage of the situation to study the transfer of activity to foodstuffs. We have followed the time-dependence of activity concentrations in herbage and milk at two farms, one in an area of very low dry deposition in Berkshire and one in Cumbria in an area of heavy rainfall where deposition occurred primarily by wet processes (Wilkins et al, 1987a). Activity loss from the grass is determined by radioactive decay, by weathering by wind and rain and by the pattern of grazing. Initial differences between the time dependence of the activity on grass at the two farms are explained by the different herd management practices and different meteorological conditions.

The rate of decline of deposited iodine 131 is dominated by its short physical half-life of 8 days. Effective half-times on pasture at both farms were in the range 4–5 days corresponding to environmental half-times of 8–15 days. The lower value is the one normally expected for iodine on growing pasture (Heinemann & Vogt, 1980; Miller & Hoffman, 1983). Iodine 131 was measurable in milk as early as May 2, albeit at very low levels, reinforcing the suggestion above that some activity had reached the UK the previous day. The concentration in milk increased rapidly to reach a maximum after 4 days and thereafter decreased with effective half-times consistent with the declining concentration in herbage.

Because of their long physical half-lives of 2 years and 30 years, caesium 134 and 137 require additional consideration. The retention half-times of caesium in grass at the Berkshire farm where a block grazing regime is operated was 23 days compared with 7 days on the Cumbrian pasture which was continuously grazed. The differences reflect both the effect of the grazing pattern and that of climate, since in Cumbria some of the activity may have been washed off by rain, whereas in Berkshire the weather remained dry. Caesium concentrations in milk rose rapidly, reaching a maximum at 2 days after deposition at the Cumbrian farm and thereafter declining with an effective half-life of 7 days (Fig. 1). At the Berkshire farm, the maximum was not attained until about 8 days after deposition and then declined only slowly during May and June. The activity concentrations of milk at both farms show dramatically the effect of winter feeding on silage cut during the early part of 1986. At the Berkshire farm, where this herbage was cut shortly after the activity was deposited, winter feeding on silage has resulted in radiocaesium concentrations in milk that are about 85% of the maxima attained in May 1986. In contrast, in Cumbria the herbage was cut later and consequently the silage used for winter feed was of lower concentration than the fresh herbage consumed in May 1986. Concentrations in milk have therefore reached only about 25% of the 1986 maxima. Concentrations are expected to decline rapidly once the cows are turned onto outside grazing in 1987, since root uptake of caesium by herbage from the soil is small at these sites.

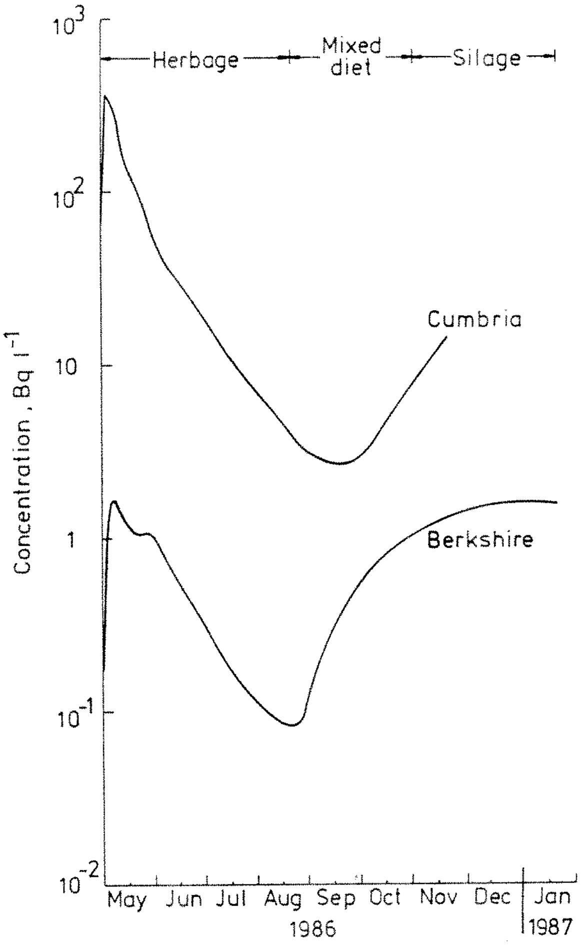


FIG. 1.

Concentrations of caesium 137 in milk at two sites, May 1986 to February 1987.

Nevertheless, we shall follow the trends with time until the activity concentrations return to their pre-Chernobyl values.

Other foods

Few vegetables were being grown outside at the time of the deposition of the Chernobyl activity. The Agricultural Departments of England, Wales, Scotland and Northern Ireland monitored a variety of vegetables and fruits; not only were the total activity concentrations well below those that would cause concern but also investigations in our own laboratories suggested that activity concentrations in many vegetables could be reduced by as much as an order of magnitude by normal culinary preparation (Wilkins et al, 1987b).

Attention soon turned to activity concentrations in meat, since, for caesium isotopes, this is a major contributor to dietary intake. Radioactive contamination of meat poses a different problem from that encountered with dairy or vegetable produce, one of potential prolonged exposure, since meat may be preserved or frozen and consumed over long periods. For this circumstance, emergency reference levels (ERLs) and the corresponding derived quantities are no longer applicable and the Agricultural Departments set intervention levels of 1000 Bq kg^{-1} total caesium activity following the lead given by the Commission of the European Communities Article 31 Group of Experts. A ban was imposed on the movement and slaughter of animals exceeding this level and a guarantee was given that no meat exceeding this level would be marketed.

In the UK as a whole, typical peak concentrations of caesium 137 in meat were 40 Bq kg^{-1} for beef and 200 Bq kg^{-1} for lamb, but in areas of high deposition average concentrations were several times these values. Concentrations were particularly high in the flesh of sheep that had grazed the high fells due to a combination of high deposition in these areas and the grazing habits of upland sheep. Initially, areas where activity concentrations were likely to exceed the intervention levels were delineated on the basis of rainfall or measured deposition, and sheepmeat sampling and measurement programmes were aimed at reducing the extent of the affected areas. Only about 10% of the total sheep population was affected, but this proportion represents over 2 000 000 animals, thus presenting an enormous monitoring programme for the Departments. Slaughter of sheep and measurement of tissue samples proved to be expensive and time-consuming; it also proved difficult to make decisions on a whole flock on the basis of a few samples because of the large variation between animals. By mid-summer 1986, *in-vivo* measurement techniques were developed and since then the agricultural departments have continued to monitor all sheep from the fells.

The situation presents an opportunity to study uptake by grazing animals and we are following the levels of radiocaesium in two flocks of sheep: one grazes pasture at a lowland farm on the Cumbrian coastal plain; the other grazes freely on the open fells. Animals from each flock have also been moved to a Berkshire farm where the intakes of radiocaesium are negligible. *In-vivo* measurements on these animals have shown that activity is lost with a biological half-time of about 15 days (Dodd, 1987), a value that is in reasonable agreement with those obtained by another laboratory (Howard et al, 1987). Concentrations in tissue of the lowland flock in Cumbria are quite low and follow the trends in activity concentrations in fodder. On the fells, high deposition in rainfall occurred and the retention time on vegetation has been much longer than that expected for lowland pasture. The fell sheep eat grass when it is available, but also root-mat, mosses and edible shoots of plants such as heathers, which have higher activity concentrations. These factors have maintained the activity concentration in tissue over the winter.

An area of uncertainty in spring 1987 concerns the uptake of radiocaesium from soil to the new growth of grass. For soils with a high clay content, caesium tends to become associated with the mineral fraction and hence to be unavailable for uptake. In contrast, the soils of the high fells are high in organic content and the caesium remains more readily available. We shall be continuing our studies of activity in vegetation, its transfer to mature sheep and the subsequent levels in lambs.

ACTIVITY IN HUMANS

Intakes of radionuclides by persons can be estimated from the activity concentrations in foods with assumptions about the origin of foodstuffs and the quantities consumed. Fortunately, the radionuclides of interest can also be measured directly in humans and this provides an independent evaluation of intake.

Iodine 131 is taken into the body by inhalation and ingestion, the latter route in general being predominant. Once taken into the body, iodine concentrates in the thyroid and the activity declines by biological elimination and radioactive decay. We made measurements on more than 100 persons resident in southern England and southern Scotland (Fry & Milton, 1986). A number of other laboratories made similar measurements (Hill et al, 1986; IPSM, 1986). In general, measured values were less than those predicted from environmental measurements and standard assumptions about intake rates.

The major dietary sources of caesium isotopes are milk, dairy products and meat; inhalation makes an insignificant contribution. When taken into the body, caesium is fairly uniformly distributed throughout soft tissues and, following rapid elimination of a small fraction, most is eliminated with a biological half-time of 110 days in adults. Half-times are shorter in younger persons. The activity in persons will depend upon dietary intake, the source of the foodstuffs and individual variations in metabolism. We have measured

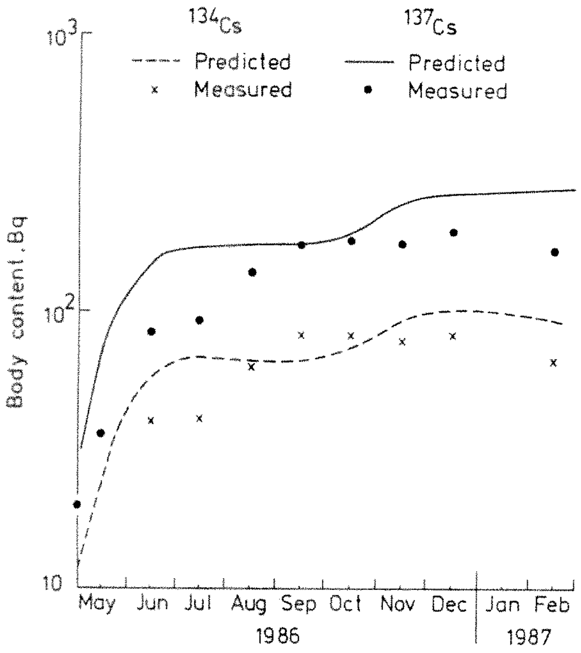


FIG. 2.

Body contents of radiocaesium in a southern England population, May 1986 to February 1987.

a number of adults at Chilton at intervals since the Chernobyl accident. The caesium 137 content has increased from its pre-Chernobyl value of about 20 Bq to a maximum of about 200 Bq attained during the autumn (Fig. 2). Since then there has been no discernible decrease. Before the accident there was no caesium 134 in this group. The initial ratio of caesium 134 to 137 in persons was about 0.5 as expected from environmental measurements, but it will of course decline because of the shorter half-life of the former isotope. Body contents in the south of England are similar to those predicted from typical concentrations in English diet. Similar levels have been observed elsewhere in England and in south Wales (IPSM, 1986) with somewhat higher levels in south-west Scotland, as might be expected from the higher concentrations in locally produced milk and meat (Watson, 1986).

Levels in people are expected to decline, but only slowly since we will continue to eat foods with low concentrations of caesium isotopes for some time to come. We shall follow levels in our local population until they return to the pre-Chernobyl values and with the co-operation of hospitals, research institutes and the nuclear industry we intend to co-ordinate all such UK measurements so as to provide an independent estimate of dose from this source.

DOSES AND HEALTH EFFECTS

We now consider doses that persons are likely to receive as a result of the Chernobyl accident. We calculate doses from all routes of exposure; they are immersion in the cloud, inhalation of airborne activity, external irradiation from deposited material and ingestion of contaminated foods.

We consider effective dose equivalents to 1-year-olds and adults and, because of the importance of iodine 131, we also consider dose equivalents to the thyroids of both groups (Morrey et al, 1987). Doses have been calculated separately for wet and dry regions in each country within the UK.

External dose from immersion in the contaminated air mass was calculated from measured values of the integrated concentrations of radionuclides in air at various locations across the UK. Doses were calculated by standard mathematical models and account was taken of the time that people spend indoors and the shielding properties of buildings. This route of exposure lasted only whilst the contaminated air mass persisted. External exposure from deposited material continues for much longer. After deposition, the external dose rate decreases due to radioactive decay, the removal of the material from the surface by natural weathering processes and, on a longer timescale, migration down through the soil. The external dose from deposited material in the first month after deposition was estimated from measured dose rates. At later times, doses were calculated from the measured deposition with allowance for radioactive decay, weathering, the time that persons spend indoors and the shielding effects of buildings.

Intake of radionuclides by inhalation has been calculated from the measured activity concentration in air and standard assumptions about breathing rates at different ages (Harrison & Simmonds, 1980). Concentrations indoors were assumed to be lower than those outdoors and allowance has been made for the length of time spent indoors. Doses were then calculated from standard dosimetric models (Greenhalgh et al, 1985).

Doses from intakes of radionuclides through food chains have been calculated on the basis of measured peak concentrations in foodstuffs, models of the time dependence of activity in each foodstuffs intake and dosimetric models. For each region of the UK, the average value of the peak concentration of each foodstuff was estimated from all the monitoring data (DoE, 1986).

Doses from all pathways have been calculated for an average individual in each area, consuming foods contaminated at the average level for that area. It is also possible to postulate the existence of hypothetical individuals in each area who consume larger than average quantities of food all contaminated at a higher than average level. Doses to such a group of hypothetical individuals have also been calculated to give an appreciation of the possible range of doses within the population.

Doses to thyroids (Table VII) are predominantly due to iodine 131 intake and will already have been

TABLE VII

TYPICAL DOSE EQUIVALENT TO THYROID IN 1ST YEAR (μSv)

Country	Infant	Adult
England	1000	190
Wales	1200	240
Scotland	1500	310
N. Ireland	2000	370
UK	1100	200

received. The average for the UK as a whole is 1100 μSv for infants and 200 μSv for adults; thyroid doses in areas of high deposition may be three or four times these values. All are well below the intervention level of 50 mSv. Next we consider effective dose equivalents for the first year after the accident (Table VIII). The average value for the UK as a whole is 30 μSv to adults; again, doses in the areas of high deposition could be a factor of six times these values. The doses received by the hypothetical most exposed group could be three or four times higher than the average individual doses in each region. Most of the dose arises from ingestion of contaminated foodstuffs, with a significant contribution from external irradiation. Both pathways will persist for some time and so we also calculate doses over all time which will, on average, amount to a 50% addition to the effective doses received in the first year.

We are all of us exposed to radiation all the time and to give some sense of perspective to these doses we should note that the average effective dose equivalent from natural sources is around 2000 μSv in every year and that there is considerable variation in this exposure (Table IX). The most important component, and the one subject to the largest variation, arises from the radioactive gas radon 222 and its decay products. Recent surveys have shown that the average effective dose equivalent in the United Kingdom from this source is 700 μSv each year, received mainly in the home. However, doses greater than 50 mSv year^{-1} may be received by the occupants of as many as 2000 homes (O'Riordan et al, 1987), and the NRPB has recently promulgated recommendations on the need to limit exposure to radon decay products in the home (NRPB, 1987).

TABLE VIII

TYPICAL EFFECTIVE DOSE EQUIVALENT TO ADULT PERSONS (μSv)

Country	1st year	All time
England	20	30
Wales	65	90
Scotland	90	150
N. Ireland	100	170
UK	30	45

TABLE IX

ANNUAL DOSE IN THE UK FROM RADIATION OF NATURAL ORIGIN (μSv)

Source	Average	Range
Cosmic radiation	300	280–310
Terrestrial gamma rays	400	200–1000
Radon and thoron decay products	800	100–100 000
Other internal radiation	370	200–400
Total	1870	1000–100 000

To consider the impact of the accident on the UK in radiological terms, we need to calculate the collective dose to the population as a whole. The collective effective dose equivalent commitment is 3×10^3 man-Sv and if we apply a standard risk factor of one fatal malignancy for 100 man-Sv (ICRP, 1977), we can estimate that the putative health impact is a few tens of deaths over all time, far too few to be discernible against the so-called natural rate of cancer deaths. Similarly, the collective dose equivalent to the thyroid is 1×10^4 man-Sv and we can estimate that there might be about 100 non-fatal malignancies of the thyroid, again too few to be observed against the natural incidence. There seems little scope for epidemiologists here.

For comparison, we note that the collective dose to the UK population from natural radiation is about 10^5 man-Sv each year and, with the same risk factor, we would expect 1300 putative cancer deaths from this exposure every year.

ECONOMIC ASPECTS

It is tempting to consider the economic impact of the accident within the UK although we will probably not know the full extent of this for some time to come. Turning first to internal interests, we find that NRPB staff effort on work related to the accident approaches three-quarters of a million pounds, although this must be small by comparison with the effort expended by the agricultural departments. The major economic impact has been felt by the hill farmers who have suffered restrictions on the movement and slaughter of their flocks. Initially, some 2 500 000 sheep in north Wales, Cumbria and south-west Scotland were subject to restrictions and around 100 000 were still restricted by March 1987. A sum of over four million pounds had been paid in compensation by early 1987; the total cost cannot be known yet.

The food industry has suffered from trade restrictions. Some imports from east Mediterranean countries affected by Chernobyl deposition have exceeded the EEC import limits and UK manufacturers have been obliged to seek alternative sources of supply, sometimes at higher cost. Other countries outside the EEC have imposed even more restrictive limits on their imports. Countries with nuclear power programmes have tended to set limits of the order of several hundred Bq kg^{-1}, whereas those without have been more restrictive, even in one case specifying absolutely zero activity. Manufacturers have suffered additional administrative overheads, they have had to pay to have their goods tested and they have faced the potential loss of overseas markets. The cost is not inconsiderable.

Lessons

To consider the effect of the accident on future emergency plans, we must look back at the lessons we have learned. Firstly, there was an overwhelming demand for measurements. As well as the environmental measurements described in this paper, there was an enormous demand from travellers, importers, shipping companies and air flight operators (Hughes & Shaw, 1986). Persons requiring individual monitoring were referred to hospitals participating in the National Arrangements for Incidents Involving Radioactivity or to the NRPB. Within the UK, there was a considerable demand for information at a local level. Although the DoE issued frequent bulletins, much of the local demand was satisfied by hospitals and local authorities. The lesson here is that there is considerable expertise around the country, in hospitals, universities and local authorities, and provision should be made for including this in any national scheme.

Information in a readily understood form must be freely available at local level as well as nationally. When individuals are concerned about their health, they turn to their doctors or their local hospitals and they may be more inclined to believe the information they obtain from these sources than what they learn from the national news. To facilitate this route of communication, information and advice must be given on a timely basis to those whom the public trusts.

The key to both of these requirements is communication. The government is currently conducting a review of emergency arrangements and we are awaiting its decision. We hope that it will give due emphasis to the two-way nature of communications. There must be a central organisation that collects data not only from the national monitoring networks described above but also from a variety of other sources, and the central organisation must ensure the flow of the information, not just onwards to central government, but also back to local officials who can explain the situation in their particular areas. In the existing emergency plans there had been no intention for the NRPB to act as an information centre, but this is certainly one of the functions we fulfilled in the first few weeks after the accident. Once our telephone number became widely known, our switchboard was jammed with callers seeking information, advice and reassurance, and most were reassured by the personal contact they made. Clearly, this demand cannot be met fully from a central source and such advice and reassurance ought to be available locally.

There remains the question of international consistency. Broadly, most countries accept the recommendations of the International Commission on Radiological Protection for levels of dose at which action should be taken in a radiological emergency (ICRP, 1984). However, the way in which the basic recommendations of dose are translated into intervention levels of activity concentrations will vary from country to country depending upon the contamination event and local factors. There are good scientific reasons why intervention levels may be different in different countries, but this may be difficult to explain, and these reasons are sometimes overturned by political decisions. Finally, there is the question of controls on international trade. A simple, uniform value of activity concentration in all foods would not be defensible scientifically, although it would be more readily accepted by public and politicians. These matters are currently under discussion by various international organisations and we must hope that they arrive at a consensus that is widely accepted without being unduly restrictive.

Summary

I had originally thought that by this time, nearly 1 year after the Chernobyl reactor accident, I would be in a position to describe fully its impact on the UK in terms of radiation doses, economics and future emergency planning. However, only one of these is reasonably clear—the radiological impact. We shall continue our measurements, particularly those of activity in persons, and doubtless we shall refine our estimates of collective dose, but they are unlikely to change significantly. We can therefore be certain that the radiological impact on the UK was small and that the health effects will not be detectable.

Predictions of the consequences of accidental releases of radionuclides have in the past, perforce, relied upon models of environmental transfer. Data on which the models are based were obtained from investigations of weapons fallout and of routine releases from nuclear facilities. The Chernobyl accident provided a situation of activity deposition that was well characterised in time and in geographical distribution, and measurements along environmental pathways will allow us to validate or refine our models. This accidental deposition reinforced the importance of some effects that we knew about—such as the importance of wet deposition—and will cause us to consider the need to take account of specific situations that we had not considered previously in adequate detail—in particular, the behaviour of radionuclides in upland ecosystems.

The overall economic impact is not yet clear and, unfortunately, is unlikely to become so until all restrictions on the movement and slaughter of sheep are removed and the farmers have received compensation. The effect on international trade may never be quantified.

Some international agencies are evaluating the consequences of Chernobyl and their reports will become available during 1987. International agreements on intervention levels are also still under discussion and it would be premature to speculate about the need for any fundamental revisions to Emergency Reference Levels and derived quantities. Similarly, we are aware of the need for revision of the national emergency plan, but we are awaiting the government decision on this. One effect of the Chernobyl accident, however, is clear: the public's awareness of radiation issues has reached a new height. Members of the public demand information and advice, and better means of communicating these must be provided. Advice to take some action may provoke unnecessary alarm, but advice that no action is required may be distrusted. We cautiously assume that any dose, no matter how small, has some deleterious effect and yet, in situations of accidental releases, we may tell the public that no actions are required to reduce doses that they may consider appreciable and avoidable. We clearly need to promote a better understanding of the nature and acceptability of the risk of radiation doses in such circumstances and we intend to do so.

ACKNOWLEDGMENTS

I am most grateful to my colleagues at Chilton and Glasgow who have provided so much of the information I have drawn upon in this lecture. I am also grateful to colleagues in other organisations for access to information and for valuable discussions.

REFERENCES

ARC, 1961. *Strontium-90 in Milk and Agricultural Materials in the United Kingdom 1959–1960*. Agricultural Research Council, ARCRL 4.

Aoyama, M., Hirose, K., Suzuki, Y., Inoue, H. & Sugimura, Y., 1986. High level radioactive nuclides in Japan in May. *Nature, 321*, 819–820.

ApSimon, H. M. & Wilson, J., 1986. Tracking the cloud from Chernobyl. *New Scientist, 111*, 42–45.

ApSimon, H. M., Wilson, J. J. N., Guirguis, S. & Stott, P. A., 1987. Modelling studies of the spread of the Chernobyl release across Europe and the long term consequences. *British Nuclear Energy Society*, (in press).

Beardsley, T., 1986. US analysis incomplete. *Nature, 321*, 187.

Cambray, R. S., Playford, K. & Lewis, G. N. J., 1985. *Radioactive Fallout in Air and Rain: Results to the End of 1984*, AERE R11915.

Cambray, R. S., Cawse, P. A., Garland, J. A., Gibson, J. A. B., Johnson, P., Lewis, G. N. J., Newton, D., Salmon, L. & Wade, B. O., 1987. Observations on radioactivity from the Chernobyl accident. *Nuclear Energy, 26*, 77–101.

Dodd, N. J., 1987. Personal communication.

DoE, 1986. *Levels of Radioactivity in the UK from the Accident at Chernobyl, USSR, on 26 April, 1986*. Department of the Environment, London, HMSO.

Devell, L., Tovedal, H., Bergtröm, U., Appelgren, A., Chyssler, J. & Anderson, L., 1986. Initial observations of fallout from the reactor accident at Chernobyl. *Nature, 321*, 192–193.

Fry, F. A. & Milton, M. I., 1986. *Thyroid Contents of Iodine-131 in UK Residents after Chernobyl*. In NRPB-M139 (HMSO, London).

Greenhalgh, J. R., Fell, T. P. & Adams, N., 1985. *Doses from Intakes of Radionuclides by Adults and Young Persons*. National Radiological Protection Board, NRPB-R162 (HMSO, London).

Hancock, R. & Woollam, P. B., 1986. *Environmental Radioactivity Measurements at BNL Following the Chernobyl Accident*. Central Electricity Generating Board. TPRD/B/0809/R86.

Harrison, N. T. & Simmonds, J. R., 1980. *Dosimetric Quantities and Basic Data for the Evaluation of Generalised Derived Limits*. National Radiological Protection Board, NRPB-DL3 (HMSO, London).

Heinemann, K. & Vogt, K. J., 1980. Measurements of the deposition of iodine onto vegetation and of the biological half-life of iodine on vegetation. *Health Physics, 39*, 463–474.

Hill, C. R., Adam, I., Anderson, W., Ott, R. J. & Sowby, F. D., 1986. Iodine-131 in human thyroids in Britain following Chernobyl. *Nature, 321*, 655–656.

Howard, B. J., Beresford, N. A., Burrow, L., Shaw, P. V. & Curtis, E. J. C., 1987. A comparison of caesium activity in sheep remaining on upland areas contaminated by Chernobyl fallout with those removed to less active lowland pasture. *Journal of the Society for Radiological Protection, 7*, 71–73.

Hughes, J. S. & Shaw, K. B., 1986. Radiation monitoring of conveyances, cargoes, passengers and crews in the UK following the Chernobyl accident: a preliminary review. *Radiation Protection Dosimetry, 15*, 207–209.

IPSM, 1986. *Chernobyl: Response of Medical Physics Departments in the United Kingdom*. Ed. by J. K. Haywood. Institute of Physical Sciences in Medicine Report No. 50.

ICRP, 1977. Recommendations of the International Commission on Radiological Protection. ICRP Publication 26. *Annals of the ICRP, 1*, 3 (Pergamon Press, Oxford).

——1984. Protection of the public in the event of major radiation accidents: principles for planning. ICRP Publication 40. *Annals of the ICRP, 14*, 2 (Pergamon Press, Oxford).

Jost, D. T., Gäggeler, H. W., Baltensperger, U., Zinger, B. & Haller, P., 1986. Chernobyl fallout in size-fractionated aerosol. *Nature, 324*, 22–23.

Linsley, G. S., Crick, M. J., Simmonds, J. R. & Haywood, S. M., 1986. *Derived Emergency Reference Levels for the Introduction of Countermeasures in the Early to Intermediate Phases of Emergencies Involving the Release of Radioactive Materials to Atmosphere*. NRPB-DL10 (HMSO, London).

Mayneord, W. V., Anderson, W., Bentley, R. E., Burton, L. K., Crookall, J. O. & Trott, N. G., 1958. Radioactivity due to fission products in biological material. *Nature, 29*, 1473–1478.

McMahon, T. A. & Denison, P. J., 1979. Empirical atmospheric deposition parameters—a survey. *Atmospheric Environment, 13*, 571–585.

MAFF, 1987. *Radionuclide Levels in Food, Animals and Agricultural Products. Post Chernobyl Monitoring in England and Wales*. Ministry of Agriculture, Fisheries and Food and Welsh Office (HMSO, London).

Miller, C. W. & Hoffman, F. O., 1983. An examination of the environmental half-time for radionuclides deposited on vegetation. *Health Physics, 45*, 731–744.

Morrey, M., Brown, J., Williams, J. A., Crick, M. J., Simmonds, J. R. & Hill, M. D., 1987. *A Preliminary Assessment of the Radiological Impact of the Chernobyl Reactor Accident on the Population of the European Community*. Published as a CEC report.

Nair, S. & Darley, P. J., 1986. A preliminary assessment of individual doses in the environs of Berkeley, Gloucestershire following the Chernobyl nuclear reactor accident. *Journal of the Society for Radiological Protection, 6*, 101–108.

NRPB, 1981. *Emergency Reference Levels: Criteria for Limiting Doses to the Public in the Event of an Accidental Exposure to Radiation.* National Radiological Protection Board, NRPB-ERL2 (HMSO, London).

——1987. *Exposure to Radon Daughters in Dwellings.* National Radiological Protection Board, NRPB-ASP10 (HMSO, London).

O'RIORDAN, M. C., JAMES, A. C., GREEN, B. M. R. & WRIXON, A. D., 1987. *Exposure to Radon Daughters in Dwellings.* National Radiological Protection Board, NRPB-GS6 (HMSO, London).

SEHMEL, G. A., 1980. Particle and gas dry deposition: a review. *Atmospheric Environment, 14,* 983–1011.

SMITH, D. M., MCALLISTER, G., WELHAM, D. & ORR, D., 1985. *Environmental Radioactivity Surveillance Programme: Results for the UK for 1984.* NRPB-R189 (HMSO, London).

SMITH, F. B. & CLARK, M. J., 1986. Radionuclide deposition from the Chernobyl cloud. *Nature, 322,* 690–691.

THOMAS, A. J. & MARTIN, J. M., 1986. First assessment of Chernobyl radioactive plume over Paris. *Nature, 321,* 817–819.

UNSCEAR, 1982. *Ionising Radiation: Sources and Biological Effects.* United Nations Scientific Committee on the Effects of Atomic Radiation 1982 report to the General Assembly, United Nations, New York.

USSR STATE COMMISSION ON THE USE OF ATOMIC ENERGY, 1986. Working document for Chernobyl post-accident review meeting, IAEA, Vienna.

WATSON, W. S., 1986. Human ^{134}Cs/^{137}Cs levels in Scotland after Chernobyl. *Nature, 323,* 763–764.

WILKINS, B. T., BRADLEY, E. J. & FULKER, M. J., 1987a. The influence of different agricultural practices on the transfer of radionuclides from pasture to milk after the Chernobyl accident. *Science of Total Environment,* (in press).

WILKINS, B. T., BRADLEY, E. J. & DODD, N. J., 1987b. The effects of culinary preparation on radionuclide levels in vegetable foodstuffs. *Radiation Protection Dosimetry,* in press.

1987, *The British Journal of Radiology*, 60, 1159–1163 DECEMBER 1987

Nuclear reactor accidents: preparedness and medical consequences

Proceedings of a one-day seminar held on April 2, 1987 in Southampton as part of the 1987 Annual Congress of the British Institute of Radiology

Chairmen: Sir Donald Acheson and Professor R. J. Berry

Medical and radiobiological basis of radiation accident management

By C. C. Lushbaugh, S. A. Fry and R. C. Ricks

Radiation Emergency Assistance Center/Training Site*, Oak Ridge Associated Universities, Oak Ridge, Tennessee, USA

(*Received April 1987 and in revised form August 1987*)

Until the recent radiation accident at Chernobyl, USSR, the medical basis for managing the care of radiation accident victims was derived from relatively few events and patients (Lushbaugh et al, 1986). While a vast literature exists on experimental radiation biology of animals, extrapolations from the research laboratory to the clinical setting are not straightforward and must be tested for validity by actual medical experience at the bedside. Such testing has been accomplished to the extent possible by studying the medical histories of accidental radiation injury cases that recount the successes and failures in worldwide medical communities (Hubner & Fry, 1979). Medical case reports, records of accident investigations, and medical reviews of this human radiation experience have been gathered in many places for use in medical education and in planning national and community responses to nuclear and other kinds of radiation disasters. The extraordinarily rapid and thorough response by the medical emergency teams sent to Chernobyl from Kiev and Moscow after the explosion there demonstrated how well such plans based on human radiation accident experience can be carried out (Legasov, 1986). The excellence of this approach was also demonstrated well by the subsequent "up-to-the-minute" therapy that the 203 seriously irradiated victims received at Moscow "Hospital No. 6" under the leadership of Soviet physicians, Drs Guskova, Baranov and Ilyin. It produced enviable medical successes since only 29 of the 203 seriously injured victims were lost (Legasov, 1986). The triage operation that resulted in the identification of the 203 persons needing hospitalisation among about 24 000 irradiated to significant but acutely tolerable doses, was an outstanding success largely because it was based on careful analysis of previous clinical radiation accident experiences from worldwide sources (Barabanova et al, 1987). These analytic results were being shared by the Soviet physicians involved in the Chernobyl response through a committee of the United Nations Scientific Committee on the Effects of Atomic Radiation at the time of the Chernobyl disaster. Other compendia and registries, both formal and informal, are available through the International Atomic Energy Agency in Vienna, the World Health Organisation (WHO) in Geneva, the WHO Collaborative Radiopathology Centres in Paris and Oak Ridge, the Radiation Emergency Assistance Center and Training Site (REAC/TS) of the US Department of Energy (DOE), in Oak Ridge (Lushbaugh et al, 1975), and that of the National Radiological Protection Board in England. Numerous other sites of excellence in radiation medicine exist in West Germany, the Netherlands, and Sweden to mention only a few.

As excellent and extensive as the human radiation accident medical records are, they fall short in most instances by failing to provide the needed radiation dosimetry correlating symptoms and signs accurately with experimentally derived animal radiation biology in which dose is known precisely. In most radiation accidents, "dose" is estimated on the basis of the timing and severity of subsequent clinical and laboratory events as in the major radiation disasters at Hiroshima and Nagasaki, the Marshall Islands, and now in Chernobyl. This "biological dosimetry" (except for cytogenetic chromosomal analysis) is still based largely upon clinical observations whereby radiation exposure levels are estimated retrospectively using scenarios often of questionable validity. Among the 29 persons from

---

*This programme is conducted for the US Government under Contract No. DE-AC05-760R00033.

TABLE I

MAJOR RADIATION ACCIDENTS: WORLDWIDE HUMAN EXPERIENCE 1944–MARCH 1987*

Number of accidents	Persons involved	Significant exposures†	Fatalities (acute effects)
284	1358	620	33
(1)	(135 000)	(24 200) (203)‡	(29)

Total number of radiation accidents in the REAC/TS Registries before and after the Chernobyl nuclear reactor disaster showing numbers of persons involved who are thought to have had more than 0.01 but less than 0.25 Gy total body irradiation and those above 0.25 Gy dose, the level of medical concern. The 203 persons shown separately were hospitalised after exposures estimated as greater than 1.0 Gy. Twenty-nine deaths attributable to radiation damage occurred in the Chernobyl accident.

*Source: DOE-REAC/TS Radiation Accident Registries.

†USDOE/NRC accident dose criteria.

‡ ≥ 100 cGy.

Chernobyl data are given in parentheses.

Chernobyl who died in hospitals in Moscow and Kiev, no physical measurements of exposure are apparently available. Therefore the bone marrow doses used in control of their therapy had to be estimated from clinical observations of the time of onset of vomiting and fever and from laboratory observations of the rate of fall in blood lymphocyte levels, and temporal curves of granulocytes and platelet levels in the peripheral blood (Barabanova et al, 1987; Legasov, 1986). Later on, in surviving patients, doses were re-estimated by observing the time of the recovery phase of granulocyte and platelet counts. These estimates proved to be adequate for making clinical decisions and providing measurements of clinical progress and of success or failure of various therapeutic modalities. But even so, without precise dosimetry, radiation medicine still remains based on clinical anecdotes of symptomatology related to retrospective estimates of dose. These new clinical results from Moscow, however, greatly strengthened the historical basis for good medical practice in cases of accidental radiation exposure and made a twofold addition to the number of fatal cases in the archives of several radiation accident registries.

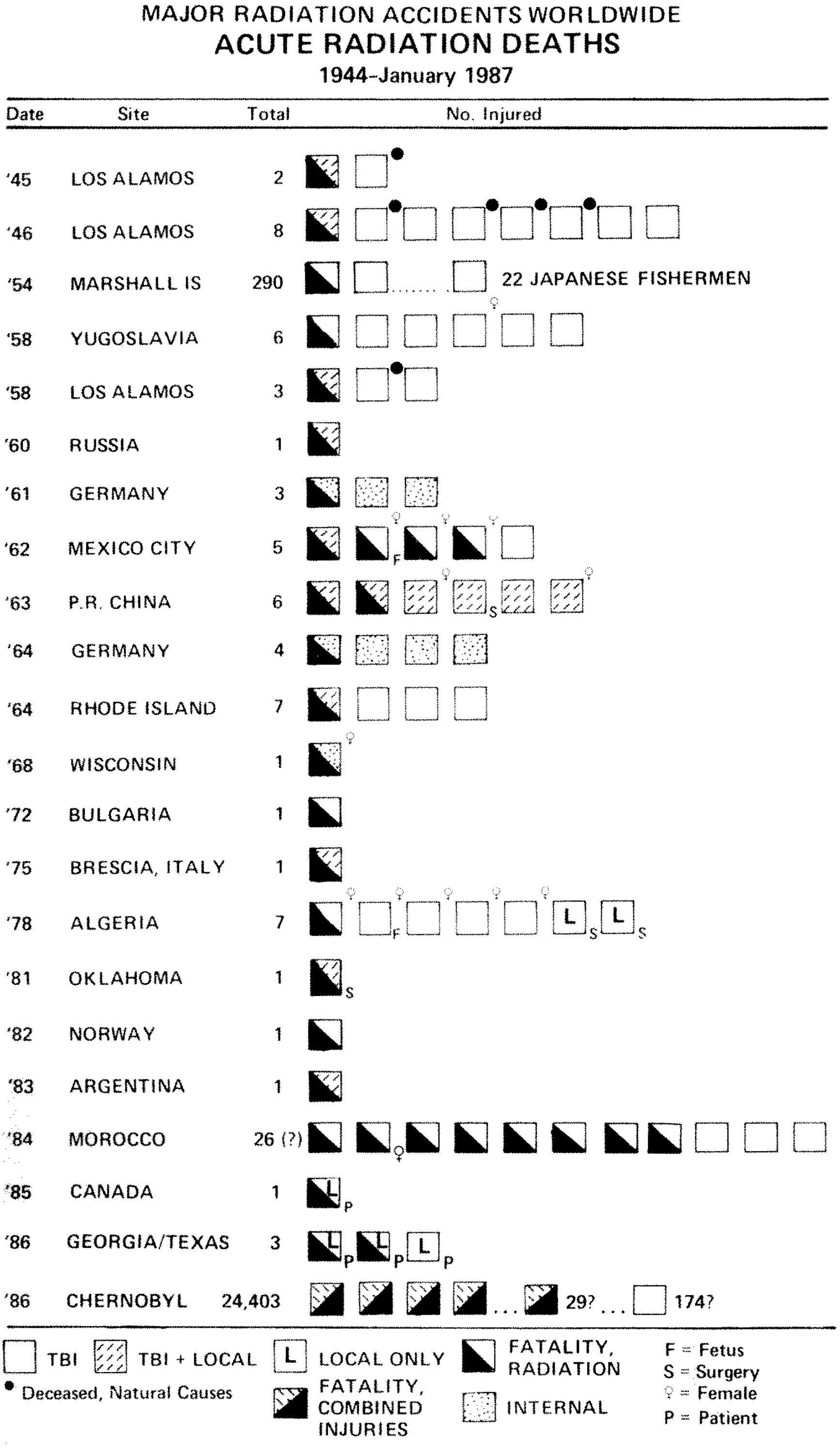
Up until the Chernobyl accident, the Registry at Oak Ridge contained 284 separate radiation accidents in which, as far as we could determine, only 1358 persons were exposed to ionising radiation (Table I). Of these persons, 620 received a dose to the whole body estimated as having been greater than 0.25 Gy, or doses to the skin in excess of 6.0 Gy. Of these 620 patients, 33 died (Fig. 1). Nine of the deaths occurred in the United States; eight others in Morocco; four in Mexico; and two each in Germany and China. Single radiation deaths are recorded in Algeria, Argentina, Bulgaria, Italy*, Japan†, Norway, Russia, and Yugoslavia†. Numerous clinical studies of these fatalities have been published and reviewed (Hubner & Fry, 1979) and these have shown that men and women react qualitatively like other mammals, particularly like larger animal species (*e.g.* bovine) and develop the same acute post-irradiation syndromes as demonstrated in other animals in experimental radiation biology. These studies also demonstrate large uncertainties concerning human dose–response relationships because our human experience is not sufficient to assess the range of radiosensitivity in the human population. Some retrospective studies of the results of human radiation therapy in which exposure measurements are usually precise have been carried out to quantify the variation in human radiosensitivity. These studies have identified factors that increase human radiosensitivity, such as the presence of fatal diseases undergoing therapy, extremes in age, and other forms of trauma with a high probability of death. At best, the results of these studies are only semiquantitative.

The Chernobyl radiation accident changed the statistics in the radiation registries dramatically (Lushbaugh et al, 1987). It is the second critical accident in which a large number of people were exposed (Fig. 2). In Chernobyl, about 135 000 persons are said to have been involved or in such danger of being irradiated at dangerous rates that they had to be evacuated from the zones in and around Pripyat, Chernobyl and Kiev. Of these approximately 135 000 persons, more than 24 000 were found to have been so located that doses of 0.25 Gy or more were received. Of these persons, medical triage chiefly identified 203 persons who were estimated to have received doses greater than 1.0 Gy because the exposed persons gave histories of acute gastrointestinal distress and vomiting within 6–24 hours of the explosion. Of these 203 persons, 129 were hospitalised in Moscow. Three persons who were too ill to be transported far were hospitalised in Kiev along with 71 others with minimal symptoms and signs of illness. The most extensive report so far (Legasov, 1986) indicates that the three heavily irradiated persons in Kiev died within the first week and 26 others died in Moscow over the next 50 days. Up to this time we do not have enough published clinical details to enable a definitive appraisal of the causes of these deaths to be made or an accurate assignment of them all to the major radiation death syndromes. We learn that most of the persons (?23 of 26) who died in Moscow suffered from skin burns of a sufficiently large area of the body to have caused death *per se*. Available clinical and laboratory information at this time is not explicit enough to enable us to estimate

---

*Countries in which the accident occurred. The deaths actually occurred in France.

†Japanese fisherman irradiated by fallout radiation in US atomic tests in the Pacific.



MAJOR RADIATION ACCIDENTS WORLDWIDE
ACUTE RADIATION DEATHS
1944-January 1987

Date	Site	Total	No. Injured
'45	LOS ALAMOS	2	
'46	LOS ALAMOS	8	
'54	MARSHALL IS	290	.... 22 JAPANESE FISHERMEN
'58	YUGOSLAVIA	6	
'58	LOS ALAMOS	3	
'60	RUSSIA	1	
'61	GERMANY	3	
'62	MEXICO CITY	5	
'63	P.R. CHINA	6	
'64	GERMANY	4	
'64	RHODE ISLAND	7	
'68	WISCONSIN	1	
'72	BULGARIA	1	
'75	BRESCIA, ITALY	1	
'78	ALGERIA	7	
'81	OKLAHOMA	1	
'82	NORWAY	1	
'83	ARGENTINA	1	
'84	MOROCCO	26 (?)	
'85	CANADA	1	
'86	GEORGIA/TEXAS	3	
'86	CHERNOBYL	24,403	... 29? ... 174?

FIG. 1.

Block diagram of the 43-year history of acute radiation deaths showing the year and location of occurrences and the total number of persons involved in each. The blocks represent each individual injured and indicate as shown in the key the type of irradiation and subsequent outcome.

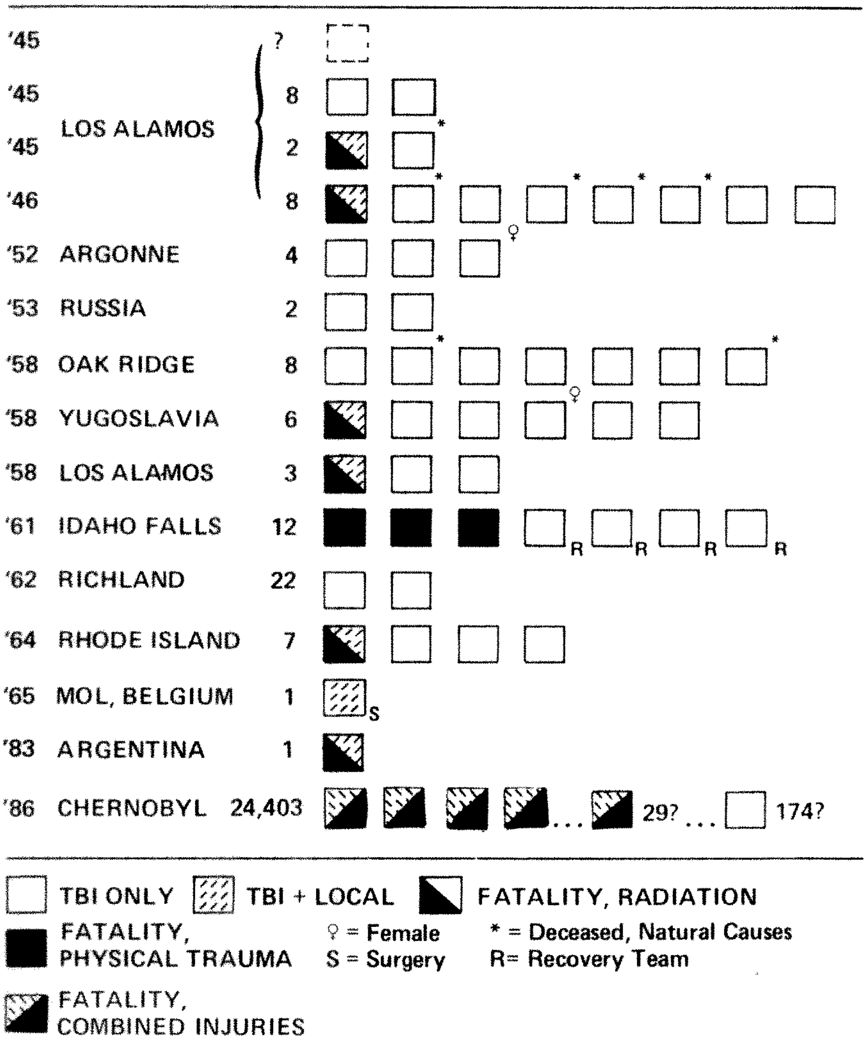


FIG. 2.

Block diagram of medical cases recorded in REAC/TS of victims of critical radiation accidents in which fissionable nuclear materials were involved. Graphical representations used in previous encodements of the kinds of injury have been updated from previous schema to show that an estimated 29 fatalities were from combined injury among 174 medically serious cases from Chernobyl (tentative estimate).

the radiation doses independently. A possible differential diagnosis of the cause of these skin lesions could include at this time: (1) thermal damage, (2) beta radiation damage or (3) toxic epidermal necrolysis, any of which in combination with total-body irradiation comprise a little known lethal irradiation syndrome known as combined injury disease (Hirsch, 1987). Experiments show that this clinical radiation syndrome results from the simultaneous effect of sublethal total-body irradiation and thermal burns, neither of which trauma would be expected to cause death if present separately. Thermal enhancement of radiation damage is well known in radiation therapy. Lethal mechanisms are not clearly defined at present, nor is it known to what extent simultaneous beta irradiation and thermal damage to the skin enhance one another. One possible explanation for death in combined injury disease is that loss of dermal integrity opens another avenue for bacterial and viral invasion, much as gastrointestinal mucosal damage does (Messerschmidt, 1986). Clinically, the syndrome appears to have a more complicated basis that involves a mutual enhancement of systemic biochemical and vascular changes that remain to be identified. The Chernobyl experience appears from afar to provide clinical substance to this concept.

To make this historical update of radiation accidents complete, Fig. 1 also identifies three radiation fatalities of a previously unreported kind which can best be typified as being caused by "computer error", a modern euphemism for another kind of human error to which all these radiation accidents can be traced.

REFERENCES

BARABANOVA, A. V., BARANOV, A. E., GUSKOVA, A. K., KEIRIM-MARKUS, I. B., MOISEEV, A. A., PIATKIN, E. K., REDKIN, V. V. & SUVOROVA, L. A., 1987. *Acute Radiation Effects in Man* (Atonimform, Moscow), in press.

HIRSCH, E., 1987. Personal communication.

HUBNER, K. F. & FRY, S. A., 1979. The medical basis for radiation accident preparedness. *Proceedings of the REAC/TS International Conference*, October 18–20, Oak Ridge, Tennessee (Elsevier North Holland, New York).

MESSERSCHMIDT, O., 1986. Whole-body irradiation plus skin wound: animal experiments on combined injuries. *British Journal of Radiology Suppl. 19*, (British Institute of Radiology, London), pp. 64–67.

LEGASOV, V. A., 1986. *The Accident at the Chernobyl Atomic Energy Site and its Consequences*. International Atomic Energy Agency Expert Conference, 25–29 August, Vienna. Section 7.5. Data on irradiation of power plant and emergency service personnel: treatment.

LUSHBAUGH, C. C., ANDREWS, G. A., HUBNER, K. F., CLOUTIER, R. J., BECK, W. L. & BERGER, J. D., 1975. REAC/TS: A pragmatic approach for providing medical care and physician education for radiation emergencies. In *Diagnosis and Treatment of Incorporated Radionuclides*. Proceedings of the International Atomic Energy Agency, World Health Organization Seminar, Vienna.

LUSHBAUGH, C. C., FRY, S. A., RICKS, R. C., HUBNER, K. F. & BURR, W. W., 1986. Historical update of past and recent skin damage radiation accidents. In *Radiation Damage to Skin. British Journal of Radiology, Suppl. 19*, 7–12.

LUSHBAUGH, C. C., RICKS, R. C., & FRY, S. A., 1987. *A US Perspective on Chernobyl*. AMA International Conference on Non-Military Radiation Emergencies, November 19–21, 1986, Washington, DC, in press.

Medical basis for the establishment of intervention levels

By J. C. Nénot

Institut de Protection et de Sûreté Nucléaire, Département de Protection Sanitaire, BP No. 6,
92265 Fontenay-aux-Roses Cédex, France

(Received January 1987 and in revised form June 1987)

In the event of an accident in a nuclear installation, the objective of the countermeasures is to reduce the detriment to individual members of the public resulting from the release of radioactive materials into the environment. Because of the variety of circumstances which will lead to the implementation of the various countermeasures, it is not possible to recommend, for the establishment of reference levels, a unique value which would be applicable in any circumstances (International Commission on Radiological Protection (ICRP), 1977; International Atomic Energy Agency (IAEA), 1981; ICRP, 1984a; World Health Organisation (WHO), 1984; IAEA, 1985). Therefore, the authorities responsible for decision-making should have a reasonable knowledge of basic data, such as the risks avoided by the implemented countermeasure and the disadvantages incurred by the individuals affected.

BASIC PRINCIPLES

If the projected dose is at such a level that serious non-stochastic effects are expected, the introduction of a given countermeasure will be almost certain. Generally, the principle for deciding whether to introduce a countermeasure or not is that the detriment to health and social life incurred by its introduction should be less than that of the dose avoided.

The general principles have been clearly stated by the ICRP (1984):

(a) Non-stochastic effects should be avoided by the introduction of countermeasures to limit individual dose to levels below the threshold for these effects.

(b) Individual risk from stochastic effects should be limited by introducing countermeasures which achieve a positive net benefit to the individuals involved. (This can be accomplished by comparing the reduction in individual dose, and therefore risk, that would follow the introduction of a countermeasure, with the increase in individual risk resulting from the introduction of that countermeasure.)

(c) The incidence of stochastic effects should be limited by reducing the residual health detriment. (This source-related assessment may be carried out by cost–benefit techniques and would be similar to a process of optimisation, in that the cost of health detriment in the affected population is balanced against the cost of further countermeasures.)

For the first two principles, the determining parameter for decision-making will be the levels of individual doses. Consequently, the various health risks which might result from an accidental exposure should be identified and quantified.

EFFECTS OF EXPOSURE

The health effects may be classified either as non-stochastic or stochastic effects (ICRP, 1977). In both cases, the organs or tissues which are known to be most likely at risk are the most exposed and the most radiosensitive ones. Because of the assessed nature of the accidental release which is most likely to occur, these organs or tissues are: the bone marrow, lung, thyroid, skin, eye lens, gonads, as well as the fetus or embryo when pregnant women are exposed.

Non-stochastic effects

For each non-stochastic effect of interest, two parameters should be considered: the threshold at which the effect appears and its relative severity.

The shapes of the dose–response relationships are generally well known (United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1982; ICRP, 1984). At a first approximation, uncertainties may seem trivial. In fact, as the slopes of the dose–response curves are relatively steep, expressing a rapidly increasing probability of revealing effect for small increments of doses, a small uncertainty in the threshold dose can involve large uncertainties in the risk evaluation. For example, an uncertainty of a factor of 2 in the dose threshold could involve an uncertainty of the same order of magnitude as the interval D_{10}–D_{90}.

Bone marrow. After an overexposure involving the bone marrow, early mortality will result from cell depletion in this tissue. If depression in peripheral blood cells is too severe, the irradiated person may die from an infection due to the loss of granulocytes or from haemorrhages due to the loss of thrombocytes combined with vascular damage (Bond et al, 1965; Lushbaugh, 1982; UNSCEAR, 1982). The value for the median lethal dose within 60 days ($LD_{50/60}$) is not known precisely: it is estimated to range from 2.5 to 5 Gy, for a homogeneous exposure (Lushbaugh, 1969; UNSCEAR, 1982; Martin, 1983; ICRP, 1984a). Higher or lower values are mentioned in the literature (National Academy of Sciences, 1967; ICRP, 1978; Lushbaugh, 1982), as well as values at the upper or lower bounds of this range (Cronkite et al, 1960; Bond et al, 1965; Lushbaugh, 1982). Whatever the absolute value, the shapes of the dose–response curves and their slopes remain comparable. A schematic example is given in Fig. 1, with a significant mortality starting around 2 Gy and exceeding 90% around 5 Gy. Such a curve will show a translation motion towards lower or higher doses in relation to individual parameters, such as the following.

(1) Sex: women seem to be more sensitive than men (Casarett, 1968).
(2) Age: extrapolation from experimental animals to man would show that $LD_{50/60}$ at birth is lower by a factor of 2 or more than in the adult; this value then decreases with aging (Casarett, 1968).
(3) Health: any disease that causes bone marrow impairment or results in a defect of the immune response, as well as some specific treatments, will be responsible for a lower $LD_{50/60}$.
(4) Therapy of the haematological syndrome: an intensive treatment will modify the prognosis completely. It has been stated that a supportive medical treatment could lead to an increase of the $LD_{50/60}$ by a factor of 1.5. It is now thought that a specific treatment (including treatment of the haematopoietic impairment, prevention and treatment of infections, and treatment of denutrition and impairment of electrolytic balance) will increase the $LD_{50/60}$ by a significant factor, about 10 Gy (US Nuclear Regulatory Commission (NRC), 1985).
(5) Protraction of exposure: in case of an accident, the time distribution of the dose may have a great importance, as the population might be exposed during long periods to the various components of the total dose. In some cases, these components can represent a significant fraction, such as the deposits of long-lived radionuclides. Extrapolation from animal experiments suggests a weighting factor of about 4 when the dose is delivered during 1 month or more (McClellan, 1982). For a 2-week exposure, this factor would be only 2.

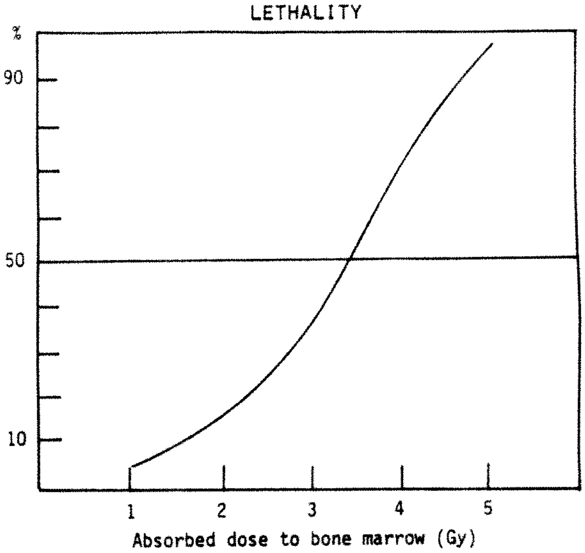


Fig. 1.

Dose–response curve for early mortality after total-body exposure to low-LET radiations.

Generally speaking, the dose–response varies with the heterogeneity of the population and with the period over which mortality is considered. It can also be assumed that mankind shows variability in size and volume, as demonstrated in various animal species. This latter parameter should not introduce a variability factor higher than 2. All of these parameters should not result in more than about 1 Gy of uncertainty on the $LD_{50/60}$ value if, reasonably, the extreme values are not taken into account.

Lung. The lung is the most sensitive organ in the thorax. In spite of its large functional reserves, its tissues have a low probability of regeneration after a large loss of cells. This organ is vital, and its exposure

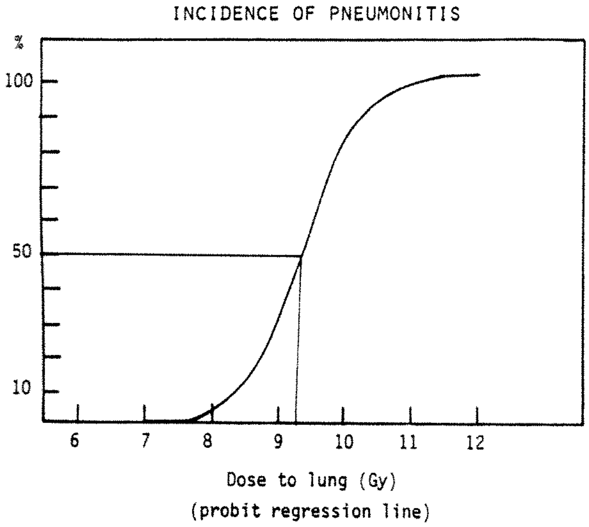


FIG. 2.

Dose–effect relationship for the development of radiation pneumonitis (from Van Dyk et al, 1981).

may be external (cloud) or internal (inhalation of radioactive materials). Following inhalation, the dose rate will vary with the composition of the release. The major change in the lung is the development of radiation pneumonitis resulting in pulmonary fibrosis. Initially, damage of alveolar lining and capillaries results in an increased capillary permeability, in oedema and inflammatory phenomena. Then, fibrosis of the alveolar septa predominates, resulting in chronic occlusive pulmonary vascular lesions. The early phase occurs within about 2 months and the terminal one after some 6–9 months. The most reliable dose–response relationship for acute exposure of both lungs shows a threshold at about 6–7 Gy, with a D_{50} at about 9 Gy (Philips et al, 1972; Van Dyke et al, 1981; UNSCEAR, 1982; Molls et al, 1986). All the observations suggest that the D_{50} estimate is relatively independent of modelling assumptions, because of the steepness of the dose–response curve (US NRC, 1985). An example is given in Fig. 2. The occurrence of death, as well as the levels of lethal doses, is very dependent upon the pattern of dose accumulation (ICRP, 1984b): the more rapid the rate of accumulation, the lower the lethal dose. Human data are too rare to allow any derivation; extrapolation from animal data results in high multiplying factors for mortality and morbidity (Michaelson et al, 1968; McClellan, 1982). For instance, the D_{50} should be multiplied by factors of about 10, 20 and 50 when the dose is delivered in 2 weeks, 6 months and 1 year respectively. These factors should be considered with great caution; however, even if imprecise, they demonstrate the effect of the dose distribution on the lung. Age or any lung diseases or vascular impairments will decrease lung tolerance to radiation. Children may be regarded as a critical group, and it has been suggested that a value of about 5 Gy for the D_{50} can be considered as reasonable. Intensive treatment may reduce doses by a factor of 2 or more (IAEA, 1978). In spite of a good level of knowledge of radiation-induced lung diseases, all of these data introduce a degree of uncertainty which should not exceed 2, when a normally distributed population is considered (Kean et al, 1981; ICRP, 1984b).

Thyroid. Although the thyroid is not considered as an especially sensitive organ to the acute effect of radiation, it should be considered in detail, since iodine isotopes are likely to be released if an accident occurs in a nuclear installation. Iodine accumulates rapidly in the thyroid after ingestion or inhalation, and may reside in the organ long enough to cause local damage. The radiation-induced diseases are various, depending upon the dose levels and the time of occurrence: acute radiation thyroiditis, chronic lymphocytic thyroiditis, benign thyroid nodules and hypothyroidism resulting in myxoedema. High doses are needed for the development of a goitre. The total ablation of the organ within a short period (2 weeks) is achieved by a dose of about 1000 Gy or more (Maxon et al, 1977; UNSCEAR, 1982). The most reliable relationship suggests an increase of risk of about 5% for each increment of 100 Gy, for doses higher than 200 Gy (US NRC, 1985). Hypothyroidism is produced by much lower doses. After deposition of ^{131}I, the threshold dose is estimated to be about 10 Gy, with D_{50} about 300 Gy (thyroid doses); after acute exposure to external low linear energy transfer (LET) radiation, this dose is reduced by a factor of 5 (Maxon et al, 1977; Maxon et al, 1980; Kaplan et al, 1983; US NRC, 1985). Figure 3 gives the dose–response relationships for both types of exposures. It shows that the risk to the thyroid is closely related to the protraction or fractionation of the exposure, *i.e.* to the isotopic composition of the accidental release and to individual metabolic characteristics. Among the latter, age is an important parameter. For example, for nodule formation, age and sex play a leading part: females present a risk of nodule formation about 2.5 times higher than males (Ron & Modan, 1984) and for embryos and teenagers the factor is 5 and 2.5 times higher than for adults respectively (US NRC, 1985).

Skin. Radiation damage to the skin may be classified schematically as erythema, wet epithelitis and necrosis, appearing above increasing thresholds of 3–8 Gy, 12–20 Gy and 25 Gy respectively. The skin responses, including severity, delay of appearance of the lesions and duration of the response, depend upon various parameters such as size of the irradiated area, depth dose distribution, exposure duration, dose rate and so on (UNSCEAR, 1982; ICRP, 1984a). Skin may be exposed to the plume and ground deposits or by direct deposits on the individual (skin and clothes), which can result in a protracted exposure if they are not removed

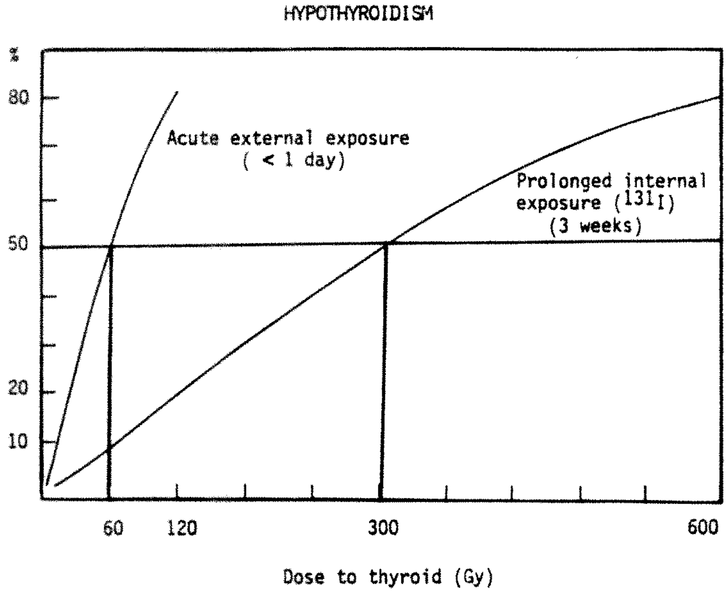


FIG. 3.

Dose–effect relationship for hypothyroidism after exposure to external (low-LET) and internal (^{131}I) exposure (from Becker, 1971; Maxon et al, 1977, 1980, 1981; Kaplan et al, 1983).

quickly. The effect of protraction on the threshold doses and on D_{50} is well known, with an average factor of 1.5–2.0 between short exposure and protracted exposure of 1–14 days (National Academy of Sciences, 1967; ICRP, 1984b). Before the Chernobyl accident it was generally believed that skin exposure following a reactor accident should not raise serious problems, as it was considered that individuals could be withdrawn fairly rapidly from this type of exposure to avoid doses above the minimum threshold. Chernobyl has shown that skin is important, especially as radiation burns involving large areas will highly complicate the aplasia and vice versa.

Eye. The eye should not be forgotten; the doses causing bone marrow depletion are of the same order of magnitude as the doses which may cause cataract. Figure 4 shows a schematic representation of the dose–response curve for cataract, with a threshold of about 1 Gy, D_{50} at 3 Gy and D_{100} at 7.5 Gy (acute exposure) (ICRP, 1984b; US NRC, 1985). Protraction seems less effective than for some other organs, since a dose higher by a factor of 2–3 and delivered in a few weeks results in the same effect. For the eye, in the case of a severe accident the only problem is acute exposure, as any protracted irradiation should be avoided. The latent period varies from 6 months to 35 years, with an average of 3 years (UNSCEAR, 1982); in a population with an average age distribution, the time distribution of the latent period shows that the elderly individuals have a much lower probability of presenting with this effect. However, for radiation protection purposes, this fact should not be taken into account in the preparedness for the accident. The other components of the eye have lower radiosensitivities, the epithelial tissues around the eye being comparable with the skin.

Gonads. The somatic risk to gonads should be taken into account. The germ cells of the reproductive system are highly radiosensitive; the threshold dose for transient sterility averages 0.15 Gy and the D_{50} is about 0.8 Gy for males and about 5–10 times higher for females (UNSCEAR, 1982; ICRP, 1984b). Recovery time in men is dose-dependent and may take many

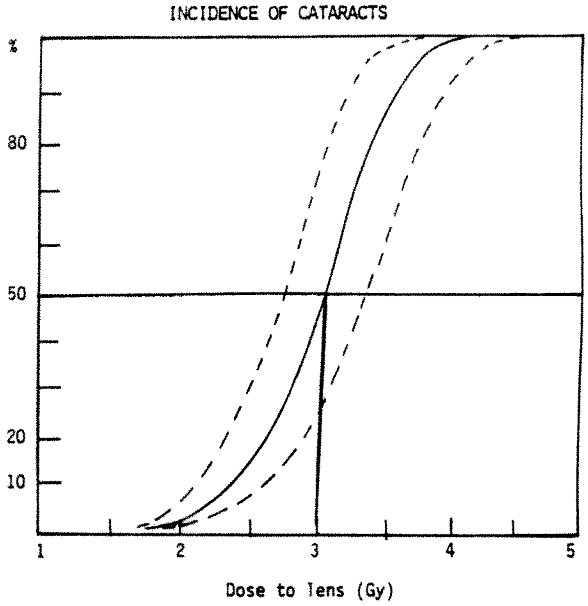


FIG. 4.

Dose–effect relationship for the development of cataract after brief exposure to low-LET radiations (from UNSCEAR, 1982).

years after exposure. Doses of 2–6 Gy or more are required for permanent sterility. The age distribution of the exposed population should be considered, as the parameter of importance is the mean age of procreation in the given population; this parameter varies widely between races, countries and ethnic group.

Embryo and fetus. Among the accidentally exposed population, pregnant women form a subgroup of particular concern because of the high radiosensitivity of the embryo and fetus (WHO, 1984). The main effects are embryonic death, gross congenital malformations, growth retardation and severe mental retardation. The LD_{50} is estimated to be minimum at conception with a value around or less than 1 Gy; it increases with age of pregnancy, with values of 2 Gy at 1 month and 3–4 Gy at birth. Risk of severe mental retardation has been proved for exposure occurring during the 8th–15th-week period (where neural proliferation in the cortex is most active), and to a lesser degree during the 16–25th-week period (corresponding to the development of the supporting tissue) (IRCP, 1984a; Otake & Schull, 1984; UNSCEAR, 1986). Between the 8th and 15th week, the incidence is reported to be apparently linear without a threshold, with a risk coefficient of 0.4/Gy. There are still many questions about the radiobiological interpretation of the complex underlying phenomena. This specific problem raises the question whether this precise subgroup should be considered as very radiosensitive. In other words, should any temporary sensitive group condition the definition of the population as a whole?

Relative severity of non-stochastic effects. The authorities in charge of planning for radiation accidents should take into account the severity of the various effects. In addition, the severity depends upon the composition of the population or the limited groups to whom countermeasures may apply. Some other effects should also be considered, not because of their severity, but because they could interfere with the normal course of the countermeasures chosen. For instance, vomiting may cause difficulties if a significant fraction of a given group is affected; the prodromal symptoms can occur at relatively low doses, with a D_{50} at about 0.5 Gy for anorexia, 1.2 Gy for nausea, 1.8 Gy for vomiting and 3 Gy for diarrhoea (Lushbaugh, 1969).

Stochastic effects

Although the risk of development of an excess of malignancies and hereditary effects as a result of the accidental exposure of the population appears at the second level only, in the quick response in decision-making, the best estimate of their nature and quantification is an element which should be available to the competent authorities. In so far as doses will be significantly higher than those normally received routinely, the use of the risk factors recommended by the ICRP should not overestimate the risk too much (ICRP, 1977). For lower doses, overestimation could justify a reduction of these factors (ICRP, 1977, 1984a). Another overestimation of the risk is introduced when the exposure is protracted over a long period as in the case of internal exposure by long-lived radionuclides. In such cases, the overestimation factor of the stochastic risk might reach values of 2 or more. In order to evaluate the total detriment, all cancers, lethal and non-lethal, should be considered. Non-lethal malignancies inevitably involve physical and psychological effects, which are more difficult to quantify than their socio-economic cost. The incidence of non-lethal cancers is known with sufficient accuracy to allow a satisfactory evaluation (ICRP, 1980a, b, 1985); for example, non-lethal cancers of the thyroid and of the skin are 20 and 100 times more frequent than the lethal ones respectively (IAEA, 1985).

CHOICE OF INTERVENTION LEVELS

Uncertainties and variability of the threshold doses for non-stochastic effect are sufficiently large for choosing lower intervention levels, in order to respect safely the first principle (*i.e.* avoidance of any serious non-stochastic effect). Such a safety factor should theoretically introduce a quasi-certainty. In fact, difficulties are greater than they actually appear. Firstly, the various thresholds cover a wide range, apply to various organs or tissues, cover health effects or symptoms of different severity and prognosis and, sometimes, involve types of exposure which cannot be compared (acute vs protracted exposure). Table I gives examples of the main non-stochastic effects to be considered and their corresponding doses. In this table, the effects have been chosen according to their possibility of occurrence and their severity; when several effects concern a single organ, such as the thyroid or skin, only the effect related to the smallest dose is considered.

The general question is to discuss the intervention levels recommended by various international organisations (Commission of the European Communities (CEC), 1982; ICRP, 1984a; WHO, 1984; IAEA, 1985). These levels do not differ significantly. A ratio of 10 between the upper and lower boundaries of the dose

TABLE I

MAIN NON-STOCHASTIC EFFECTS AND RELATED DOSES (ACUTE EXPOSURE)

Organ	Effect	D_0 (Gy)	D_{50} (Gy)
—	Vomiting	0.5	2
Bone marrow	Aplasia	1	3.5
Lung	Pneumonitis	6	9
Thyroid	Hypothyroidism*	10	300
Skin	Erythema	3	6
Eye	Cataract	1	3
Testes	Transient sterility	0.15	0.85
Embryo (2 weeks)	Death	0.5	1.2

*After intake of ^{131}I.

range within which the decision-maker acts with regard to non-radiological parameters is almost constant. One of the simplest efficient countermeasures is sheltering. This measure should therefore be considered at the lowest dose level. A comparison of these recommended levels, *i.e.* 5–50 mGy to the whole body, 50–500 mGy to the thyroid, lung or any single organ preferentially irradiated, and the threshold doses for the main effects obviously demonstrates a safety factor, even for the upper boundary doses. At these levels, quantification of stochastic effects appears uncertain. However, in spite of this security, the competent authorities should be aware of the whole risk encountered by the population, for both planning and decision-making.

REFERENCES

Bond, V. P., Fliedner, T. M. & Archambeau, J. O., 1965. *Mammalian Radiation Lethality: a Disturbance in Cellular Kinetics.* (Academic Press, New York.)

Becker, D. V., McConahey, W. M., Dobyns, B. M. et al, 1971. The results of the thyrotoxicosis therapy follow-up study. In *Further Advances in Thyroid Research,* Vol. 1. Ed. by K. Fellinger and R. Hofer (G. Gistel und Cie, Vienna), pp. 603–614.

Casarett, A. P., 1968. *Radiation Biology.* (Prentice-Hall, Englewood Clift, New Jersey.)

CEC, 1982. *Radiological Protection Criteria for Controlling Doses to the Public in the Event of Accidental Releases of Radioactive Material.* A guide on emergency reference levels of dose from the group of experts convened under Article 31 of the Euratom Treaty, Brussels (CEC, Luxembourg).

Cronkite, E. P. & Bond, V. P., 1960. Diagnosis of radiation injury and analysis of the human lethal dose of radiation. *US Army Forces Medical Journal, 11,* 249–260.

IAEA, 1978. *Manual on Early Medical Treatment of Possible Radiation Injury.* Safety Series No. 47 (IAEA, Vienna).

——1981. *Planning for Off-site Response to Radiation Accidents in Nuclear Facilities.* Safety Series No. 55 (IAEA, Vienna).

——1985. *Principles for Establishing Intervention Levels for the Protection of the Public in the Event of a Nuclear Accident or Radiological Emergency.* Safety Series No. 72 (IAEA, Vienna).

ICRP, 1977. Recommendations of the International Commission on Radiological Protection. ICRP Publication 26. *Annals of the ICRP, 1(3),* (Pergamon Press, Oxford).

——1978. The principles and general procedures for handling emergency and accidental exposures of workers. ICRP Publication 28. *Annals of the ICRP, 2(1)* (Pergamon Press, Oxford).

——1980a. Problems involved in developing an index of harm. ICRP Publication 27. *Annals of the ICRP, 1(4),* (Pergamon Press, Oxford).

——1980b. Statement and recommendation of 1980 Brighton Meeting of the ICRP. *Annals of the ICRP, 4(3/4),* (Pergamon Press, Oxford).

——1984a. Protection of the public in the event of major radiation accidents: principles for planning. ICRP Publication 40. *Annals of the ICRP, 14(2),* (Pergamon Press, Oxford).

——1984b. Non-stochastic effects of ionizing radiation. ICRP Publication 41. *Annals of the ICRP, 14(3),* (Pergamon Press, Oxford).

——1985. Quantitative basis for developing a unified index of harm. ICRP Publication 45. *Annals of the ICRP, 15(3),* (Pergamon Press, Oxford).

Kaplan, M. M., Garnick, M. B., Gelber, R., Li, F. P., Cassady, J. R., Sallan, S. E., Fine, W. E. & Sack, M. J., 1983. Risk factors for thyroid abnormalities after neck irradiation for childhood cancer. *American Journal of Medicine, 74,* 272–280.

Kean, T. J., Van Dyk, J. & Rider, W. D., 1981. Idiopathic interstitial pneumonia following bone marrow transplantation: the relationship with total body irradiation. *International Journal of Radiation Oncology, Biology, Physics, 7,* 1365–1370.

Lushbaugh, C. C., 1969. Reflections on some recent progress in human radiobiology. In *Advances in Radiation Biology.* Ed. by L. G. Augenstein, R. Mason & M. Zelle, (Academic Press, New York), Vol, 3, pp. 277–314.

——1982. The impact of estimates of human radiation emergency management. In *The Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack.* Proceedings of a Symposium sponsored by the National Council on Radiation Protection and Measurements (NCRP) held in Reston, Virginia, USA, April 27–29, 1981 (NCRP, Washington, DC), pp. 46–57.

Martin, J. H., 1983. Human survival radiation exposures levels. *Journal of the Society for Radiological Protection, 3,* 15–23.

Maxon, H. R., Thomas, S. R. & Chen, I. W., 1981. The role of nuclear medicine in the treatment of hyperthyroidism and well differentiated thyroid adenocarcinoma. *Clinics in Nuclear Medicine, 6,* 87–98.

Maxon, H. R., Thomas, S. R., Saenger, E. L., Buncher, C. R., & Kereiakes, J. G., 1977. Ionizing radiation and the induction of clinically significant disease in the human thyroid. *American Journal of Medicine, 63,* 967–978.

Maxon, H. R., & Saenger, E. L., Thomas, S. R., Buncher, C. R., Kereiakes, J. G., Shafer, M. L. & McLaughlin, C. A., 1980. Clinically important radiation-associated thyroid disease. *Journal of the American Medical Association, 244,* 1802–1805.

McClellan, R. O., 1982. Health effects from internally deposited radionuclides released in nuclear disasters. In *The Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack.* Proceedings of a Symposium sponsored by the National Council on Radiation Protection and Measurements (NCRP) held in Reston, Virginia, USA, April 27–29 1981 (NRCP, Washington, DC), pp. 28–39.

Michaelson, S. M., Orland, K. T. & Howland, J. W., 1968. Radiation time intensity and pathophysiologic correlations in whole and partial body X-irradiated Beagles. In *Proceedings of a Symposium on Dose Rate in Mammalian Radiation Biology.* CONF-680410 (NTIS, Springfield), pp. 7.1–7.21.

Molls, M., Budach, V., & Bomberg, M., 1986. Total body irradiation: the lung as critical organ. *Strahlentherapie, 162,* 226–232.

National Academy of Sciences, 1967. *Radiobiological Factors in Manned Space Flight.* Ed. by W. H. Langham. Report of the space radiation study panel of the Life Sciences Committee. Space Science Board, National Academy of Sciences, National Research Council (NRC) Publication 1487 (NAS, Washington, DC).

Otake, M. & Schull, W. J., 1984. *In utero* exposure to A-bomb radiation and mental retardation: a reassessment. *British Journal of Radiology, 57,* 409–414.

PHILIPS, T. L. & MANGOLIS, L., 1972. Radiation pathology and the clinical response of lung and oesophagus. *Frontiers of Radiation Therapy and Oncology*, *6*, 254–273.

RON, E. & MODAN, B., 1984. Leukemia, thyroid cancer and CNS tumors following childhood scalp irradiation: Israel Tinea study. In *Radiation Carcinogenesis: Epidemiology and Biologic Significance*. Ed. by J. D. Boice Jr & J. F. Fraumeni Jr (Raven Press, New York).

UNSCEAR, 1982. Report to the General Assembly, with Annexes. *Ionizing Radiation: Sources and Biological Effects* (United Nations, New York).

——1986. Report to the General Assembly, with Annexes. *Genetic and Somatic Effects of Ionizing Radiation* (United Nations, New York).

US NRC, 1985. *Health Effects Model for Nuclear Plant Accident Consequence Analysis*, NUREG/CR-4214, SAND 85-7185.

VAN DYK, J., KEANE, T. J., KAN, S., RIDER, W. & FRYER, C. J. H., 1981. Radiation pneumonitis following large single-dose irradiation: a re-evaluation based on absolute dose to lung. *International Journal of Radiation Oncology, Biology, Physics*, *7*, 461–467.

WHO, 1984. *Nuclear Power: Accidental Releases, Principles of Public Health Actions*. WHO Regional Publications, European Series No. 16 (WHO, Regional Office for Europe, Copenhagen).

Experience of a specialised centre in the organisation of medical care of persons exposed during a nuclear reactor accident

By N. M. Nadezhina

Institute of Biophysics, Ministry of Health, Zhivopisnaye 46, 123182 Moscow, USSR

(Received September 1987)

Following the Chernobyl accident, selection for emergency hospitalisation, from among the exposed persons, those in whom the development of acute radiation disease (ARD) was predicted with the highest degree of probability was made within 36 h. This selection was based on the criteria for early diagnosis adopted in the USSR: time and manifestations of primary and local reactions, expression of lymphopenia and neutrophilic leukocytosis. Specialised centres in Kiev and Moscow were chosen for hospitalisation in order to provide maximum medical assistance.

In the first 2 days, 129 patients were admitted to a specialised hospital in Moscow. In the first 3 days, 84 of the patients developed ARD, Degree of severity II–IV, and 27 patients developed ARD, Degree I, thus supporting the criteria for initial sorting of the patients.

Degree II–IV ARD was diagnosed within the first 3 days; verification of diagnosis of Degree I ARD required, as a rule, a longer period of observation (up to 1–1.5 months). The main diagnostic and prognostic criteria required for the determination of medical handling of patients and the choice of therapeutic modalities, including indications for bone marrow transplantation, decontamination and so on, were defined within the first 3 days of their stay in the centre.

In addition to the above criteria of time and manifestations of a primary reaction, the occurrence of lymphopenia, a direct method of analysing the frequency of aberrations in bone marrow cells, was used within the interval from the first hours of exposure up to 3 days post-exposure. In the first 10–14 days, the time of occurrence and degree of thrombocytopenia, and the time of detection and expression of leukopenia and of granulocytopenia, were also regarded as criteria of the severity of disease. Quantitative assessment of a dose to the bone marrow was based on the number of dicentrics per 100 cells in PHA-stimulated peripheral blood lymphocyte cultures.

The time course of skin changes within a period of the first days up to 2 weeks post-exposure was estimated semi quantitatively in accordance with common clinical parameters.

The course of the disease and its possible outcome initially determined on the basis of the aforementioned criteria correlated well with the expected prognosis based on the subsequent development of the disease.

In the casualty departments of the specialised centres, all patients were subjected to dosimetric control. The patients were again thoroughly washed and admitted to wards. Oral administration of potassium iodide distributed since the first day, was continued. Treatment was provided along the following main lines.

(1) Prevention and treatment of infectious complications.
(2) Substitution therapy with blood cells for bone marrow syndrome.
(3) Detoxification therapy and parenteral feeding to deal with the extensive skin burns, oropharyngeal and intestinal syndromes and toxicoseptic status.
(4) Intensive correction of water–electrolyte metabolism in patients with intestinal syndrome and toxicoseptic status determined by burns and agranulocytic infections.

The prevention of infectious complications was based primarily on the aseptic handling of the patients to combat exogenous infectious complications. With this purpose in view, all the patients with Degree II and higher bone marrow syndrome were accommodated in single units within a common hospital ward and subjected to special antiseptic regimes: ultra-violet sterilisation of the air, strict rules to be observed by the staff including washing of the hands before entering the wards, individual overalls and masks available in the wards and treatment of shoes on a mat soaked in an antiseptic solution. Microbic contamination values were controlled. These procedures ensured a low level of micro-organisms in the air: not more than 500 colonies/m^3.

The absence of exogenous bronchopulmonary infections (pneumonia) in the patients with Degree II–IV ARD, provided evidence of the effectiveness of such an antiseptic regime, as reported by us earlier (Baranov et al, 1978, 1983). Biseptol and nystatin were administered 1–3 weeks before the occurrence of agranulocytosis in all the patients with Degree II–IV bone marrow syndrome, for prevention of endogenous infections. In case of fever, two or three wide-spectrum antibiotics of the aminoglycoside group (Garamycin, Amikin), cephalosporins (Kefzol, cefamezin, cefobid) and semisynthetic penicillins active against pyocyanic infections (carbenicillin, pipracil) were injected intravenously.

In over half of the cases, fever was combatted with the administration of such a schedule of antibiotics. If agranulocytic fever was not combatted during the first week with these antibacterial drugs, amphotericin B was administered empirically.

Herpes-type viral infections (*Herpes simplex* of the facial skin, lips and oral mucosa) were combatted with Acyclovir.

This schedule of empirical antibacterial, fungicidal and antiviral therapy proved to be very effective as there were practically no deaths due to infection in the patients with the bone marrow form of ARD, even in the most severe forms (without burns).

One of the obvious achievements in the therapy of those patients with severe radiation disease was the use of fresh donor platelets. Platelet concentrate was obtained by a method of four-fold thrombocytapheresis from a single donor in each individual case.

Haemorrhagic signs or a decrease in the level of platelets below 20 000/l (approximately 300×10^9 platelets) served as indicators for platelet concentrate transfusions.

Platelet concentrate and the other blood components were irradiated before infusion, to a dose of 15 Gy using a common type of gamma therapeutic apparatus to prevent graft-versus-host disease.

The effectiveness of platelet transfusions was confirmed not only by the absence of life-threatening haemorrhages with prolonged (over 2–4 weeks) and severe thrombocytopenia (less than $5\text{–}10 \times 10^3$/l) but also by the absence of any haemorrhagic signs in the majority of the patients. An average of three to five platelet transfusions was required for the treatment of one patient with Degree III severity of bone marrow syndrome.

During the first 3 days after irradiation, the first group of patients with irreversible suppression of myelopoiesis was selected in accordance with the above rules when spontaneous recovery would not be expected (*i.e.* at a dose of 6 Gy or more). The difficulty in choosing HLA-identical donors was that it was necessary to define exactly an HLA phenotype in a great number of patients within the first 3 days after irradiation and before the lymphocyte count dropped to very low values.

Considerable organisational difficulties were associated with the rapid location and examination of a great number of potential donors from among the relatives (in total, 100 persons were examined).

In the long run, only 13 transplantations of allogenic bone marrow were carried out between the 4th and 16th day after irradiation. In six cases, human embryonic liver cell transplantation was performed in the absence of bone marrow donors.

Bone marrow transplantation did not become a decisive therapeutic method even in this group, because the patients died as a result of non-bone marrow radiation injuries, dermal and intestinal, before bone marrow engraftment could be expected. At the same time temporary or incomplete donor bone marrow engraftment was noted in the other six patients due to the fact that these patients' immunity was not completely suppressed by irradiation. It was concluded that bone marrow transplantation could be used in irreversible myelopoietic injury caused by whole-body γ irradiation at doses above 6–8 Gy.

The nature of the skin injuries, rather superficial though very extensive β-radiation dermatitis, required mainly conservative therapy (anticoagulants, drugs improving microcirculation, bactericidal and anti-inflammatory drugs for local use). A Soviet-made drug, lyoxanol, proved particularly effective. Surgical intervention was rarely required.

Oropharyngeal syndrome was treated mainly by local use of mucolytics with antiseptics and mechanical removal of tenacious mucus.

It should be noted that each patient with Degree III–IV of severity of bone marrow syndrome, particularly in combination with radiation burns, requires individual round-the-clock nursing (highly qualified nurses specialised in intensive therapy). The therapeutic effect can be regarded as satisfactory.

Deaths occurred only among patients with Degree III–IV ARD and over 70% of deaths were due to severe, extensive, incurable burns.

It should also be emphasised that specialised medical assistance to patients with ARD can best be rendered in a hospital with a special casualty department and dosimetric, karyological and bacteriological laboratories.

Finally we express our gratitude to the medical staff for their selfless work.

REFERENCES

Details not supplied.

1987, *The British Journal of Radiology*, *60*, 1171–1174 DECEMBER 1987

The role of NHS hospitals in the preparedness for nuclear accidents*

By P. J. Bourdillon, M.B., F.R.C.P.

Department of Health and Social Security, Alexander Fleming House, Elephant and Castle, London SE1 6BY

(*Received July 1987*)

There are currently two National Health Service (NHS) circulars providing guidance on the measures to be taken in the event of release of radioactivity into the environment. The first of these, Health Circular HC(76)52, published in 1976, deals with national arrangements for incidents involving radioactivity. This circular is concerned primarily with accidents involving radioactive substances in transit, or at locations where radioactive substances are not normally found. It also gives guidance on the precautions to be taken when handling patients who may have been contaminated by low levels of radioactivity.

The second Health Circular, HC(85)24, which was published in July 1985, describes the emergency arrangements to be adopted by government departments and gives advice on the plans needed by Health Authorities at the local level for dealing with accidents at civil nuclear installations. It was issued as a supplement to the Health Circular on Major Accidents (HC(77)1) published in 1977.

The purpose of this paper is to describe the two health circulars, to bring their essential features together in one document, and to discuss them in the light of the Chernobyl accident.

NATIONAL ARRANGEMENTS FOR INCIDENTS INVOLVING RADIOACTIVITY

The national arrangements for incidents involving radioactivity, the NAIR Scheme, are co-ordinated by the National Radiological Protection Board (NRPB). The police will normally be the first authority to be informed of a transport accident or other incident in a public place. Consequently the basis of NAIR is that the arrangements will be invoked by the police. For this purpose the United Kingdom is divided into areas of assistance based on police forces. Assistance is provided in two stages: the first enables the police to call upon an experienced person who can advise them on action, and the second provides more sophisticated resources should these be necessary. Each police-force area has been allotted first- and second-stage assistance centres. First-stage assistance is provided in most police areas by hospital medical physicists. Second-stage assistance is provided by radiation staff from nuclear power stations and other, similar establishments. In case of difficulty in contacting their allotted first-stage participant, the police should contact the first-stage participant from a neighbouring hospital before requesting help from the allotted second-stage source of assistance.

The hospitals whose medical physicists have agreed to provide first-stage assistance are given in one of the appendices to the circular. Initial assistance consists of advising the police or local authority whether there is a potential hazard from radioactivity and, where there is, giving advice on the action necessary to minimise and contain the danger. It is accepted that hospital radiation staff have relatively limited resources. They will not be expected to cope with incidents involving the spread of contamination unless they are very minor. When the medical physics staff are unable to deal with the incident unaided, they should advise the police to obtain second-stage assistance from establishments such as the United Kingdom Atomic Energy Authority (UK AEA), the Central Electricity Generating Board, British Nuclear Fuels Limited (BNFL) or the Ministry of Defence (MOD) (see Fig. 1).

The second part of the health circular is concerned with the handling of casualties contaminated with radioactive substances. Radioactive substances are in use in industry, medicine, research and teaching and incidents involving the release of radioactive substances may occur at any of these premises as well as in transit. Clearly, any incident involving radioactivity may give rise to casualties who, as well as being contaminated, will require treatment for their injuries. There are nearly 50 hospitals in England that have agreed to accept contaminated casualties and to advise on and assist with the decontamination of personnel. These hospitals are listed in another appendix of the circular and their location is shown in Fig. 2.

Should an ambulance crew be the first to become aware that radioactive substances are involved at any incident they attend, they should notify the police immediately. Where the need for life-saving treatment appears to override the need for decontamination, ambulance crews must take the casualty to the nearest accident and emergency department, whether or not it is in one of the hospitals that has agreed to receive casualties contaminated with radioactive substances. If the hospital receiving the casualty is not one of these 50 hospitals, it should obtain advice and assistance from one of them on the decontamination of the casualties, of the ambulance, of the ambulance crew and of any other staff involved. When the need for life-saving treatment does not override the need for decontamination, the casualties should be taken to one of the 50 hospitals

---

*© Crown copyright 1987.

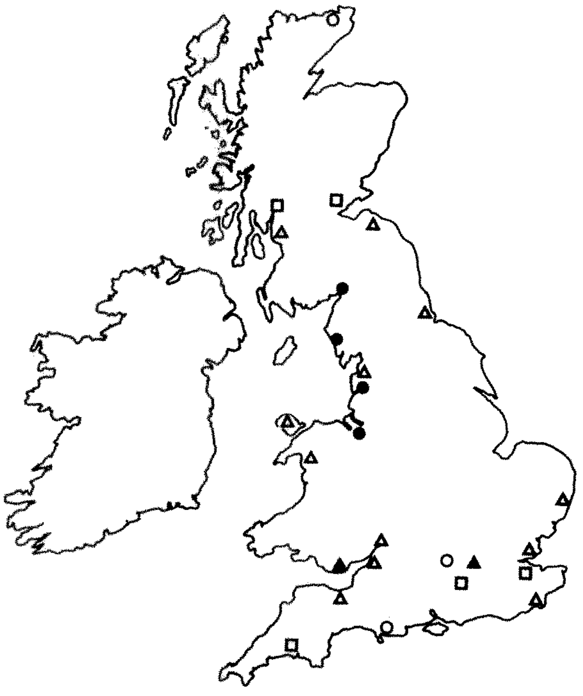


FIG. 1.

Nuclear establishments in the UK. ● BNFL establishments, ○ UKAEA establishments, △ Electricity Board nuclear power stations, □ MOD establishments, ▲ Amersham International plc establishments.

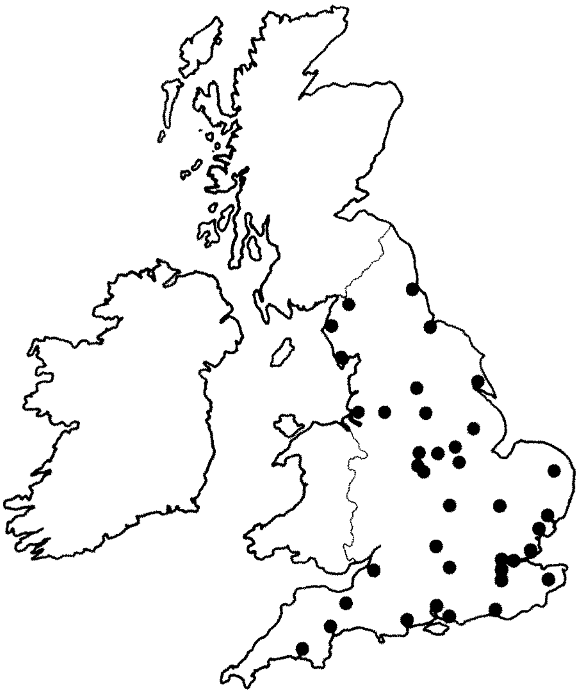


FIG. 2.

The locations of the English hospitals that have agreed to accept contaminated casualties and to advise on and assist with the decontamination of personnel.

and the ambulance crew should ask their control to alert the hospital concerned. It is not intended that these 50 hospitals should treat casualties affected by high radiation doses such as might occur from an accident in a nuclear power station. In 1976, when the circular was issued, facilities for the treatment of people suffering from whole-body irradiation existed at only four hospitals: the Hammersmith Hospital, the Middlesex Hospital, the Royal Marsden Hospital at Fulham Road and the Royal Marsden Hospital at Sutton, all of which are in the London area. The Hammersmith has since withdrawn from the scheme. The important requirements are for protective isolation and haematological support. There now exist a number of hospitals throughout England that can provide the necessary expertise, particularly those undertaking bone marrow transplantation.

The fourth appendix of the circular gives guidance to hospital and ambulance staff on the management of casualties contaminated by low-level radioactive substances. The basic principles are as follows.

(a) Life-saving treatment will override all other action.
(b) Expert advice from a radiation physicist should be obtained from one of the hospitals participating in the NAIR scheme.
(c) Care is needed to avoid the spread of contamination. If available, protective clothing (overalls and rubber/plastic gloves) should be worn when dealing with the patient.
(d) Everything that comes into contact with radioactive substances (*e.g.* patients' clothing, swabs, dressings, instruments, gloves and overalls) should be collected in plastic or paper bags for subsequent monitoring; ideally, fluid used for washing should likewise be retained in suitable containers.

The appendix also recommends some initial decontamination procedures.

(a) Washing with soap and water will effectively remove contaminated material from the skin in most cases. Initial treatment and any necessary washing to remove as much of the suspected contamination as practicable should be done in a designated "dirty" area which may not necessarily be within the accident and emergency department, but may have to be if life-support is necessary.
(b) Open wounds should be irrigated. Special care needs to be taken in the cleaning of areas near the eyes and in preventing the spread of possible contamination to other parts of the body.

(c) It is inadvisable to excise wounds unless contamination is obvious or unless surgically indicated, before expert advice from a radiation physicist is available.

HEALTH SERVICE ARRANGEMENTS FOR DEALING WITH ACCIDENTS AT CIVIL NUCLEAR INSTALLATIONS

The precautions taken in the design and construction of nuclear installations in this country, and the very high safety standards applied in operating and maintaining them, make it highly unlikely that accidents will occur which might affect the public. But, however remote the risks, all operators of nuclear installations are required to prepare emergency plans for dealing with an accidental release of radioactivity. These plans cover both emergency procedures at the site and off-site arrangements to protect the public, including monitoring up to 20 miles and evacuation up to 1.5 miles. Local authorities, the police and emergency services are closely involved in the preparation of these plans, which are tested regularly in exercises monitored by the Nuclear Installations Inspectorate. In the event of its proving necessary to extend emergency action to a wider area around the site, evacuation and other appropriate measures would be extended in accordance with emergency plans for dealing with a wide range of civil emergencies, which would be activated by the police and local authorities.

To help those in the NHS who are responsible for implementing the health circular to understand the global arrangements, the Health and Safety Executive's handbook *Emergency Plans for Civil Nuclear Installations* is reproduced as one appendix to the circular. The NRPB document *Advice for General Practitioners in the Event of a Civil Nuclear Emergency* is reproduced as another. The circular itself points out that the emergency arrangements for health authorities must actively involve all health regions and districts within a radius of 40 km from a nuclear installation. While the nuclear-site emergency plans refer only to the distance (40 km) from the site at which the site operator will provide radioactivity monitoring, the health circular recognises that people may seek medical advice at distances greater than 40 km, and it recommends that health authorities should give some consideration to the need to extend their arrangements.

IMPLICATIONS OF CHERNOBYL

Following Chernobyl, the general public looked directly to the health service for specific and personal reassurance. Members of the public returning from visits to eastern Europe with complaints such as diarrhoea, sickness or headaches sought advice from their general practitioners or from local hospitals. Government statements tried to steer returning travellers to hospitals able to offer monitoring and decontamination facilities. These hospitals dealt with numerous worried people in the days immediately after Chernobyl and are deserving of our congratulations for the way the staff rose to the occasion with the minimum of advice. Current thinking is that, from the outset, anxious travellers will be directed to designated NHS hospitals where monitoring can be carried out. It is not envisaged that special facilities will be set up at air or sea ports. It must be assumed that those at significant risk of exposure in foreign countries will have been monitored by the competent authorities of the affected countries before being permitted to proceed on their journey, as occurred when the students returned from Kiev and Minsk. Details of the nearest UK hospital with monitoring facilities will need to be provided to port authorities and their health sections to enable their staff to advise disembarking passengers on where to go.

Monitoring on a large scale, even for a few days, will tie up equipment and staff otherwise used for the treatment of the sick. Therefore it is necessary to be clear who should be offered monitoring. It is important that decisions are taken centrally and promulgated as soon as possible to hospitals providing monitoring, to port authorities and, via the media, to the public. Government plans for dealing with any future external accidents are being drawn up and these will provide for an organisation which can take such decisions. In the light of this national advice, NHS hospitals will be able to attach priorities to requests for monitoring and to arrange counselling for those who do not need monitoring.

There is an obvious case for uniformity of monitoring. This can only be achieved by disseminating information on the radionuclides involved in the particular incident and the radiation levels which are significant. Measurements will need to be recorded in a standard form suitable for collating and capable of being used, if necessary, in long-term follow-up studies of those monitored. The Department of Health and Social Security (DHSS) anticipates an important role here for the NRPB in giving hospitals advice on what to measure and to record.

It is not proposed that the NHS should take on major tasks that are not directly related to the monitoring of people, for instance, the monitoring of ships, aircraft, road vehicles or rail rolling stock or their cargoes. Although, in addition to the monitoring of people and their luggage, the idea that NHS hospitals with the appropriate expertise may be required to carry out some environmental monitoring tasks is being considered.

The need for national arrangements for coping with an external accident means that additional advice will be required by Health Authorities. It is also necessary to consider whether the circular, HC(85)24, on domestic accidents should be revised. An accident in the UK would probably require the provision of a similar scale of monitoring services for travellers within the UK as is envisaged for a foreign accident. Further guidance on the protection of individuals, including the use of substances to accelerate the removal of ingested or inhaled radionuclides from the body, as well as on the use of potassium iodate, is indicated.

1987, *The British Journal of Radiology*, *60*, 1174–1177

Thinking about the treatment of radiation casualties and the facilities required by them has moved on since 1976, and the opportunity will be taken to update the advice on these issues.

Current DHSS health circulars on handling incidents involving the release of radioactivity into the environment from within the UK are reasonably comprehensive. The health circulars do not yet cover satisfactorily the consequences of a foreign incident. Staff at the Department of Health are now working on the necessary additional guidance, and will update the current health circulars in due course.

United Kingdom nuclear reactor design and operation

By B. Edmondson, B.Sc., Ph.D., F.Eng.

Nuclear Co-ordination Group, CEGB, Sudbury House, 15 Newgate Street, London EC1A 7AU

(Received July 1987)

This paper will consider briefly two main points. First, why one should feel confident that UK nuclear plants can be operated safely. This will be done by highlighting a number of basic principles of safe reactor design to show what they mean and how they are applied. Second, the case in which matters went so disastrously wrong, at Chernobyl, will be examined relative to the points considered in the first part of the paper on UK reactors.

The main features of nuclear plant design can be considered by reference to an advanced gas-cooled reactor (AGR) (Fig. 1). The core is an assembly of graphite bricks acting as the neutron moderator. It contains vertical channels in which the fuel elements are stacked. Each fuel element is an assembly of rods made up of pellets of uranium dioxide in a stainless steel can. Heat is produced by fission of the uranium atoms in the UO_2, and this process gives rise to the radioactive

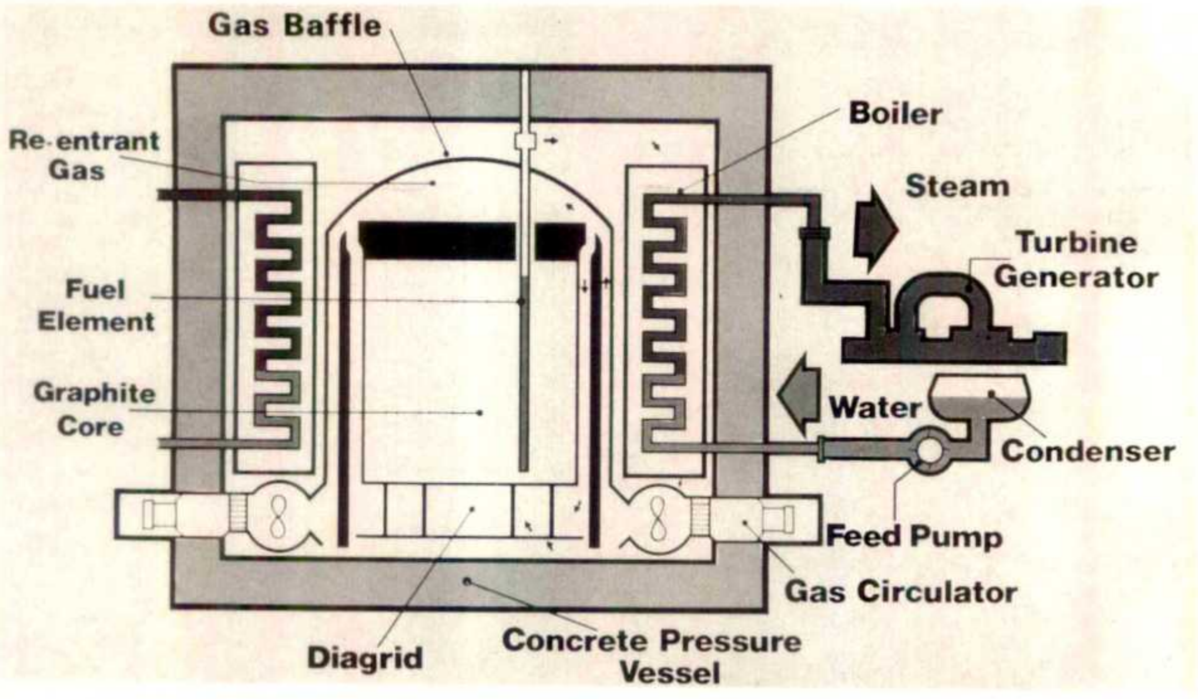


FIG. 1.
Advanced gas-cooled reactor.

species which, with the UO_2, are contained in the stainless steel can. Heat is taken away by a flow of pressurised carbon dioxide gas driven up the channels by circulators. The hot CO_2 is passed into the boilers, flowing over tubes containing water which is turned into steam to drive the turbine generators. The carbon dioxide is retained at pressure inside the pressure vessel, a massive pre-stressed concrete structure. This vessel serves another purpose, to absorb direct radiation and to contain any radioactive material which may get into the gas stream. The nuclear reaction is regulated by control rods, which absorb the neutrons and which are also available to shut the reactor down.

MAJOR PRINCIPLES IN UK REACTOR SAFETY DESIGN

A number of major principles govern reactor design in the UK. The first is that there shall be multiple barriers to the spread of radioactivity. In the case of the AGR, the barriers are the fuel cans and the pressure vessel. Thus, a major issue of AGR plant safety is that the plant shall be designed to minimise the chance of fuel-can failure. Let us use this as an example of how safety matters are pursued.

The fuel-can barrier may, in principle, be breached if it overheats, since this could involve excessive corrosion, deformation or melting, in the ultimate. For what reasons might overheating occur? Noting that heat is produced by the nuclear reaction in the fuel and is taken away first by the circulating pressurised gas and then by the production of steam in the secondary circuit, there are several general possibilities.

Too high a rate of the nuclear reaction.
Loss of coolant.
Loss of coolant pressure.
Loss of coolant circulation.
Loss of secondary circuit function as a heat sink.

Overheating would therefore only result from a fault condition, and a major component in the task of avoidance of fuel-can overheating is the detailed examination of faults, their causes, sequences, consequences and prevention. The principal assurance of safety lies in the avoidance of faults of course but, given their inevitability, great weight is laid on the requirement for their detection and limitation by instrumentation and control devices.

In the case of potential fuel-can damage by overheating, the requirement is equipment to detect temperature changes, neutron flux changes, coolant pressure changes, failure of gas circulators, loss of pressure and water flow in the secondary circuit, amongst other parameters. It also means provisions for shutting the reactor down, promptly and safely, and automatic methods of ensuring the plant is cooled adequately after shutdown.

None of this should be unexpected. It is in fact plain common sense, and these general principles will apply in safety engineering of any item of plant such as major chemical installations, transport systems and so forth. What is special about the nuclear power field is the demand for extreme reliability in the detection and control of faults. How is this reliability achieved? Apart from the obvious point of the use of reliable components, two important principles of nuclear plant safety can be summarised as "redundancy" and "diversity". By "redundancy" is meant multiplicity of safety systems, in parallel, to achieve the same safety end. A simple case is that each AGR has eight gas circulators, only one of which is necessary to keep the reactor cool after it is shut down. Similarly, there are very many control rods available to shut down the reactor, only a small proportion of which are actually needed. By "diversity" is meant separate safety systems which are sufficiently different that simultaneous failure from a common cause can be ruled out. In an AGR a simple example is that injection of a neutron-absorbing gas, nitrogen, into the reactor is available to shut the plant down. This is in addition to the control rods which are the first line of defence for this purpose.

Another principle of sound safety design is that the reactor should have a natural defence built into it via the physics of its design. In gas-cooled reactors, as the conditions of the reactor change to increase the rate of reaction, the accompanying temperature changes act so as inherently to limit the reaction. This is expressed by saying that the coefficients connecting the rate of the nuclear reaction and the consequent temperature changes are negative. For this reason there is in fact no possibility of a natural divergent power increase as the reactor conditions change. The significance of this will appear later in regard to the Chernobyl disaster.

A final principle concerns the operator and his actions. In UK designs there is no reliance on the operator to maintain the plant within its main safety parameters. This is done by designed-in automatic means. In addition, everything is done to limit the need for operator action to control fault situations. In fact, in the latest plant the design is such that operator intervention to control any fault is not needed for 30 min.

These safety principles can be summarised as follows.

Multiple barriers.
Redundant safety systems.
Diverse safety systems.
Stability inherent in the physics of the design.
No reliance on the operators to maintain plant within its safe envelope of parameters.
Limited reliance on the operators to control fault conditions.

THE RBMK REACTOR DESIGN

Chernobyl was a case where things went tragically wrong. How does it look against the principles listed above? Consider in particular, the later ones, connected with inherent stability and the involvement of the operators.

As is well known, the RBMK reactor design is

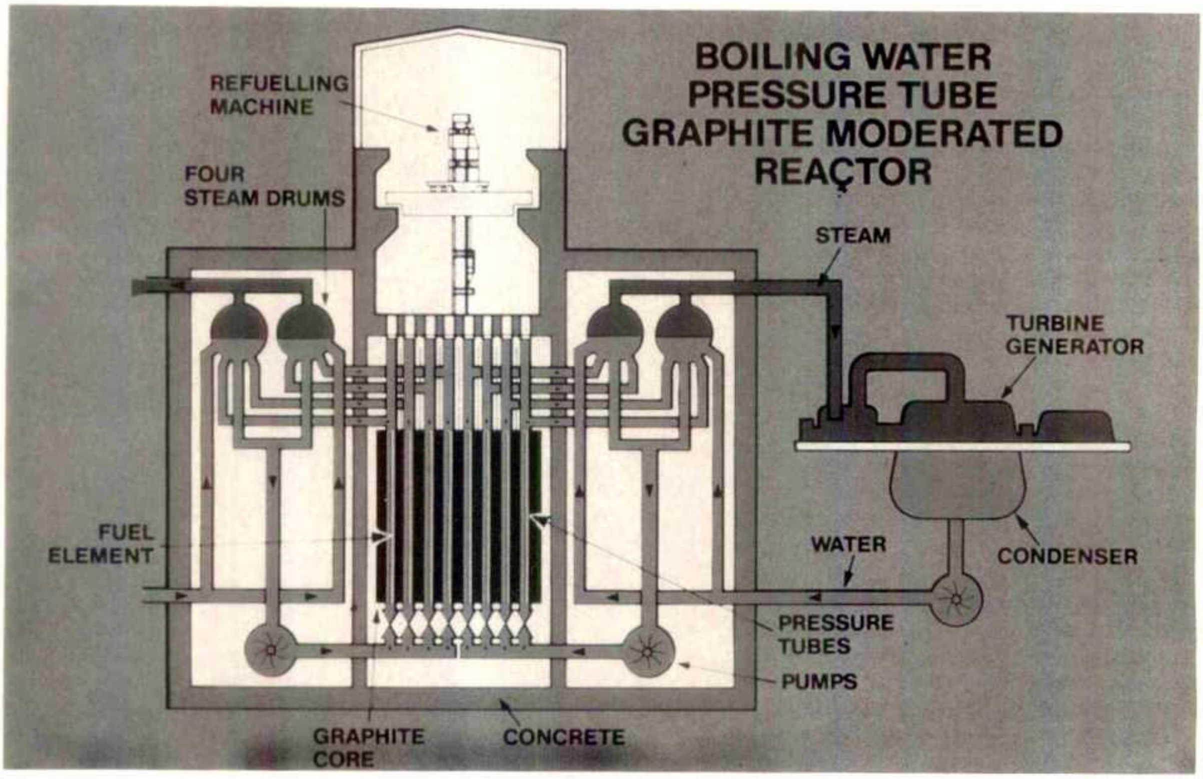


FIG. 2.
Chernobyl (RBMK) type reactor.

unique to the Soviet Union and very different from anything built or contemplated in the UK (Fig. 2). The core is an assembly of graphite bricks, with vertical channels. In these channels are pressure tubes, in which water at high pressure flows upwards past the fuel elements. As it flows up the pressure tubes the water is turned into steam to drive the turbines. The fuel is UO_2 in zirconium alloy cans, and the nuclear reaction is regulated by neutron-absorbing control rods.

In relation to the Chernobyl accident, Academician Legasov said at the meeting sponsored by the International Atomic Energy Agency in Vienna, that the designers of the RBMK plant had suffered a tremendous psychological blockage in not foreseeing the extent to which the operators might wilfully mismanage the plant. This puts the two important general issues in a nutshell: the actions of the operators and the link with the design which was the basic cause of the accident.

Certainly, as is well known, the operators grossly mishandled the situation, wilfully violating several important operating rules. It remains, however, to deal with the question of why these actions led to the disaster, and it is this issue that should be looked at against the principles of safe design considered above.

WEAKNESSES THAT LED TO DISASTER

In the RBMK design of plant, water boils in the pressure tubes. The effect of this is to reduce the amount of liquid water in the core. Water is a neutron absorber and, by itself, boiling in the RBMK reactors necessarily enhances the rate of the nuclear reaction. This is described briefly by saying that the coefficient which connects the reaction rate with steam void formation is positive. It means that the act of boiling in the RBMK reactor is such as to give inherent instability, contributing to the possibility of a divergent power increase as the reactor conditions change. There are, of course, compensating features, with coefficients of opposite sign arising from the power-determined temperature changes in the fuel. In operation at high power these latter effects are overriding and the outcome is inherent stability. At low power, however, and this is the crucial point, the void coefficient rules and the reactor is inherently unstable. It was this instability which gave rise to the uncontrolled power excursion and destroyed the reactor.

What was the means by which this unstable situation was to be avoided? Simply, the operators were instructed not to operate the plant continuously below 20% of full power and they were required to maintain a particular disposition of control rods to minimise the adverse effect of the void coefficient. Thus, total responsibility for maintaining the plant within the appropriate limits lay with the operators and depended entirely upon their following operating instructions of absolutely vital safety import.

It will now be clear why the last two safety principles listed above are of such significance. In my view, the root cause of the Chernobyl disaster lay not in the failings of the operator, but rather in the designed-in low-power instability, and the way this feature placed so much responsibility for safety on the operators' shoulders. This was the purport of Academician Legasov's statement mentioned earlier. My opinion is given great weight by the energetic backfitting programme undertaken for the operating RBMK reactors, which is aimed to correct these two features.

In conclusion, I began by setting out what seemed to me to be the set of reactor design principles which assure safety. Adherence to these principles gives the greatest confidence in the safe operation of nuclear plant in this country. Paradoxically, the Chernobyl disaster reinforces this view, when the root causes of the accident are viewed against certain of these principles.

Emergency planning

By J. K. Wright

CEGB, Courtenay House, 18 Warwick Lane, London EC4P 4EB

(Received May 1987)

Let me first of all say that if I were to put any relative weight on the two topics "plant safety" and "emergency planning", I would stress the importance of getting the plant's design and operation right. What I mean by this is that "prevention" is always better than "cure". For this reason, the Central Electricity Generating Board (CEGB) places great emphasis on ensuring that, even if a serious fault were to occur, the design of the plant and the way in which it is operated should prevent releases of radioactivity that would require off-site evacuation. Thus, while it is impossible to say that all reactor faults will be prevented, serious accidents simply must not be allowed to happen. Our emergency planning is based on making sensible provisions for action in case something does go wrong, in spite of the very low probability that provisions will ever be needed.

This point was recognised more than 25 years ago by the designers of the early Magnox power stations. These stations were built by some of the best engineers in the country at the time, who had the experience of the 1957 Windscale accident very much at the front of their minds. They designed the plant to have large margins, and were well aware of the concepts of diversity and redundancy that Dr Edmondson has discussed (see previous paper). Over the lifetime of the Magnox stations we have increased the diversity and redundancy of some of the more significant features so that the Magnox stations are, in fact, very safe. However, these plants were designed at a time before probabilistic risk assessment techniques were fully developed and instead, what has been described as a "deterministic" approach was adopted.

As part of this approach, the designers developed the concept of the so-called "maximum credible accident", and early thinking on emergency planning was based on this accident. People were not so naive as to suppose that larger accidents could not be postulated but considered that, since these were so unlikely, it was sensible to base detailed emergency plans on this so-called maximum credible accident, or (as it is now called) "reference accident". The maximum credible accident they envisaged was one where there was failure of one of the bottom coolant ducts linking the boilers to the pressure vessel at the early Magnox stations. If this failure led to a hole in just the right place and of just the right size, it was feasible that flow stagnation might occur for a period of time in the reactor core, with the result that the coolant would, for this period, cease to collect heat from the fuel element. The temperature of the fuel would then rise and the designers set the power level at which the Magnox stations were permitted to operate in such a way that in this worst event there was only one chance in a hundred of a single channel suffering clad melt and oxidation of the fuel, with release of fission products into the atmosphere through the hole in the coolant duct. At present, we are well beyond the halfway point in the likely lifetime of the Magnox stations. We have experienced no inkling of a duct failure, and our confidence in the low likelihood of this accident ever occurring remains very high. However, you will, of course, remember that we do have detailed emergency plans for such an accident.

Before I describe the arrangements that we have to cope with this reference accident, let me discuss how we

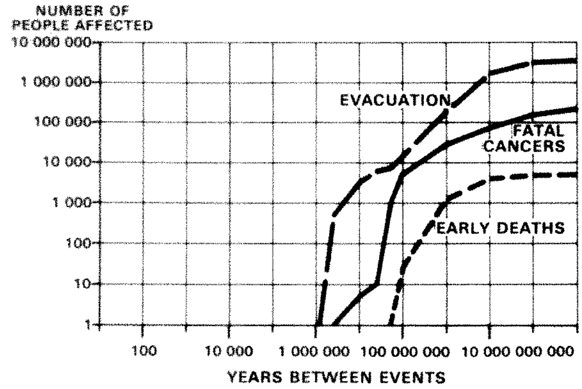


FIG. 1.
Effects from PWR accidents. Degraded core: years between events.

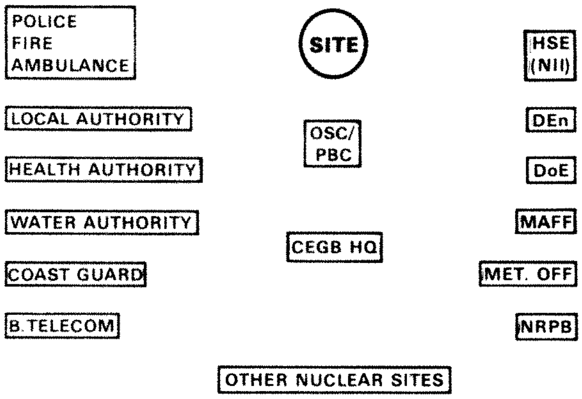


FIG. 2.
Emergency planning—organisations involved.

approach the safety of reactor systems today. Figure 1 shows the number of people who would need to be evacuated, eventually contract cancer, or suffer early death, as a function of the number of operating years between such a catastrophic event for the case of Sizewell reactor design. It will be seen that we are talking about such a major accident once in something like 10 million years. This evidence was presented to the Sizewell Inquiry, and the Inspector, Sir Frank Layfield, in his report, judged that this probability was sufficiently low for it to be a tolerable risk.

Figure 1 represents a brief summary of an enormous amount of work and analysis that has to be carried out in order to deduce these curves, and illustrates part of the modern approach to safety analysis.

But let me now return to what happens if we have a reference accident in one of our Magnox power stations. If the radioactive release from the affected fuel channel were to occur under unfavourable meteorological conditions, it is possible that we could get into a situation where action should be taken to reduce the population dose by counter-measures, including the issue of potassium iodate tablets, and the evacuation of people from their homes out to a distance of about 1.5 miles downwind of the reactor. Figure 2 shows the organisations which would be involved in such an event. For the first few hours the focal point for the activity would be the emergency controller at the power station itself. He would be in contact with the police and the emergency services, and appropriate action would be taken. This action would include the setting up of an Operational Support Centre (OSC), which is essentially a communications centre and a headquarters to control all the off-site aspects of the incident, and is situated at a distance of perhaps 10 miles from the reactor. The detailed arrangements for managing these off-site measures are being looked at as part of a Government review of emergency planning, but I will explain the arrangements as they stand at the present time. The CEGB would be responsible for co-ordinating activity within the OSC for about a day, by which time a Government Technical Adviser (likely to be a Deputy Chief Inspector of the Nuclear Installations Inspectorate (NII)) arrives to take charge. I have described the OSC as a communications centre and, as such, it has links to all those shown in Fig. 2 who are directly involved. There are also links to the Nuclear Emergency Briefing Room in Whitehall, which is the primary link with the Government machine; this would enable, for example, national resources to be obtained if appropriate. There is also a link to the Nuclear Emergency Information Centre at the headquarters of the CEGB, and in this way the entire resources within the CEGB are accessible. Figure 3 shows these links. One of the difficulties experienced when the cloud from Chernobyl passed over the UK was that, since there was no emergency at any UK nuclear installation, there was no trigger to lead to the setting up of an OSC and all the communications associated with it. Each nuclear power station has a formal nuclear emergency

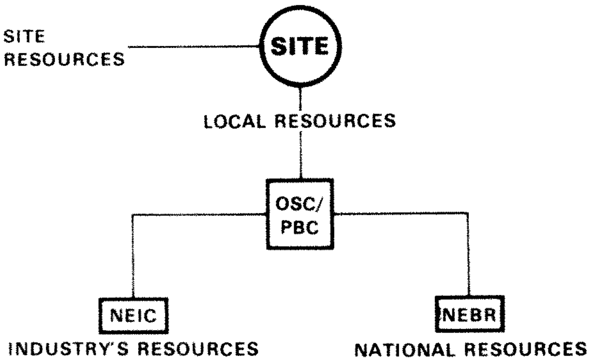


FIG. 3.
Emergency planning—resources.

TABLE I
CHERNOBYL—TYPICAL DOSES

Place	People	Doses
Site	Emergency teams	Few Sv (few hundred rem)
Pripyat (~2 km)	45000	15–50 mSv (1.5–5.0 rem)
Region <30 km	135000	up to 200 mSv (up to 20 rem)

exercise each year, which is witnessed by people within the CEGB's Health & Safety Department, and by inspectors of the Nuclear Installations Inspectorate. In addition, we have a number of exercises at OSCs each year, at which all those who have a role to play are invited to take part. The CEGB has published its emergency plans and detailed handbooks. These only give part of the picture, of course, since many organisations have a role to play, and each has their own emergency plan which dovetails into that of the CEGB.

Now I would like to move on to the question of what would happen if there was a more serious accident. The position is under review by Government at the present time. However, the Prime Minister told the House of Commons in December: "The existing plans are addressed specifically to an accident occurring within the UK, and cover both the emergency procedures at the site and offsite arrangements to protect the public. They continue to provide a valid basis for the response to any nuclear accident in the UK". The criticism is often raised that people were evacuated out to 30 km from Chernobyl, and yet we have detailed evacuation plans to only 1.5 miles, and general evacuation plans beyond that. In some way there is an inference that the general plans are inadequate. The real situation is that, for most disasters in the UK, we have no detailed evacuation plans. Instead, we rely entirely on general plans to respond to these emergencies. Let us look at a few examples. The public saw Chernobyl through, for example, the eyes of *The Sun* newspaper with the headline: "70000 Red Tots Perish"! I do not want to belittle the seriousness of Chernobyl, but with exaggerations like that it is no wonder that the general public put nuclear matters in a different category from all other risks. They come to the conclusion therefore that we must have detailed evacuation plans for this scale of accident. Is this logical? Let us have a look at some other types of disaster that could occur. In the recent Mexico City earthquake, 25000 people were killed, 40000 injured, and 31000 made homeless. We would not, of course, expect such an earthquake to occur in the UK, and so the public understand why it is that we have no plans to cope with it, other than very general plans. However, let us have a look at the real probabilities. We can expect a serious earthquake to occur in Sheffield once every 10000 years. I have chosen Sheffield, but it could be almost any other city in the UK. Compare this with the probabilities in Fig. 1 for accidents to a pressurised water reactor (PWR) at Sizewell where numbers like once every 10 million years were being shown. People query the adequacy of our detailed evacuation plans for such accidents at Sizewell, but they never question our plans to cope with serious earthquakes, which might be one thousand times more frequent. Let us have a look at another example, the floods in the Philippines which killed 1300 people and made 1000000 homeless. Well, we don't have such floods in England—or do we? In 1970, before the Thames Barrier was completed, there was a chance of 1/50 that London would be flooded each year. This probability was regarded as sufficiently high as to warrant the building of the Thames Barrier, and so now we are protected—or are we? In fact, there is still a probability of 1/1000 that a surge tide would overcome the barrier—an eventuality for which we have only the most general emergency evacuation plans. What I have tried to show from these examples is that in the nuclear industry we have extremely detailed plans against improbable events, and general plans for the most unlikely events. In most other parts of our life we have only general plans to cover the improbable events.

But, you may say, Chernobyl did happen. The Russians' response to that accident once it had happened was spectacularly successful. How would we have coped against such an accident in the UK? I have heard people say that we would not have been able to cope at all. I believe this to be untrue. Table I shows the doses to the people who were evacuated from the region near Chernobyl, as presented by the Russians in Vienna in August 1986. I was delighted to hear Dr Komarov say today that these doses are, in fact, now recognised to be overestimates of the true situation. The first people to be evacuated were those from the town of Pripyat, which is just outside the nuclear installation. Those people were evacuated about 36 h after the accident. Was this slow? No, it was not, because if one looks at the recommendations of the National Radiological Protection Board (NRPB) about when to evacuate these people, you will see that you start taking such a counter-measure when the whole-body dose is 10 rem. Doses to the public in Pripyat were only 1.5–5.0 rem. Could we have evacuated the people who live within a few miles of any of our power stations within a period of 36 h? I would suggest to you that the answer is yes—without any difficulty at all. The next group of people out to 30 km were again quite properly evacuated over a period of about a week or so. Could we, given a week, manage to evacuate people within 30 km of our nuclear power stations? I would suggest that the answer is yes. It may not be generally recognised that evacuations occur quite frequently. They are managed by the police and our emergency services in an efficient manner. Some evacuations are shown in Table II. May I draw your attention in particular to the first item—the Mississauga evacuation. Here 216000 people were evacuated from a 65 square-

1987, *The British Journal of Radiology*, 60, 1180–1182

TABLE II
RECENT INCIDENTS RESULTING IN EVACUATION

Location	Year	Substance	Event	No. evacuated
Mississauga (Canada)	1979	Chlorine	Fire (rail)	216 000
Wealdstone	1980	Propane	Leak	2000
Barking	1980	Sodium chlorate/cyanide	Fire/explosion	7000
Stalybridge	1981	Hexane	Fire	250
Ipswich	1982	Fertilisers	Fire	1000
Salford	1982	Sodium chlorate	Fire/explosion	700
Middlesbrough	1984	Epichlorohydrin	Leak (road tanker)	300

mile area of Mississauga, a suburb of Toronto, during a period of 19 h following a train derailment, fire, and leak of chlorine. This was done in a systematic way starting with those closest to the accident, and gradually extending the scale of evacuation. The culture of Canada which permitted such an evacuation is not dissimilar to that of the UK. I have no doubt that, faced with a comparable large-scale emergency, our own emergency services would cope equally successfully.

In conclusion, I would like to come back to the starting point. We must—and indeed do—bend over backwards to ensure that accidents will, in practice, not happen. If they should happen, then we have very detailed plans to cope with them. Equally, our national resources would be available and, I am sure, would serve the country well if we were ever faced with a serious accident on, say, the scale of Chernobyl.

Nuclear emergencies: medical preparedness

By R. A. F. Cox, M.A., M.B., B.Chir., F.F.O.M.

Central Electricity Generating Board, Courtenay House, 18 Warwick Lane, London EC4P 4EB

(Received April 1987 and in revised form June 1987)

Speakers at this symposium and other spokesmen have explained why an accident such as that which occurred at Chernobyl could not happen in the UK. Nevertheless, the events at Chernobyl have caused the public to seek reassurance that we are fully prepared for a nuclear emergency, even on a lesser scale than that at Chernobyl.

It has been a condition of the Central Electricity Generating Board (CEGB) operating licence that there should be a comprehensive emergency plan which is tested every year under the auspices of the Nuclear Installations Inspectorate. From a medical point of view, the basis of the plan is that the Central Electricity Generating Board should be responsible for the management of any casualties which may occur within the perimeter of a nuclear plant. At the same time it should furnish the local civil and health authorities with all the information which they may need to prepare for the reception of casualties and to take whatever action they deem appropriate for the population at large.

The total number of persons employed at nuclear stations varies between 400 and 1400 but rarely is the total number on site at any one time. At all nuclear sites there is a group of nominated first-aiders who, in addition to holding the First Aid at Work Certificate, are trained to the CEGB Occupational First Aid Certificate, and are also trained in decontamination techniques of skin, wounds, and special areas such as hair, nose, teeth and eyes. This training is carried out under the supervision of the site nursing officer and involves regular practice sessions and several refresher courses.

The initial treatment of casualties will depend upon the designated first-aiders but, if an emergency occurs during normal working hours when the site nursing officer is on duty, she will assume responsibility for attending to the medical aspects of the casualties, will supervise any decontamination that is required and will communicate with the responsible medical officer. If she is absent at the time of the emergency she will be called back to the site. The local Area Medical Officer of the CEGB will be notified and will travel either to the location or to the local hospital receiving the casualties, according to circumstances. The Chief Medical Officer or his deputy will travel to the Operational Support Centre which will have been set up in the vicinity of the accident but remote from the emergency site. There he will be available to give advice to the co-ordinating team of senior managers. This advisory role of a Senior Medical Officer is a vital one in any major emergency situation, nuclear or otherwise. It requires an experienced doctor to assess priorities and to advise on the appropriate disposition of casualties and to give appropriate help to those people dealing with public information, while in the front line of an emergency situation, a doctor can do little more for the patient than a well trained and skilled first-aider. It is also the responsibility of the Chief Medical Officer to ensure that the medical planning, training and provision is appropriate and adequate.

In almost all cases, radiation problems are secondary to what might be considered conventional injuries. This, indeed, was the experience at Chernobyl where burns, fractures and injuries from flying debris were all more serious to life and limb than the radiation. The effects of even relatively high doses of radiation will not become apparent for many hours or even days, during which time the patient may well die of other injuries if these are not attended to. Priority must be given to countering shock, resuscitation and the control of bleeding. Good sound principles of first aid must take precedence over decontamination procedures. Decontamination will take place on site and the simple removal of all clothing will reduce contamination by about 80% but this should not unnecessarily delay moving a seriously injured person to hospital. While contamination of clothes, skin, hair or wounds is plausible in the context of an accident at a nuclear site, it is not inevitable nor even likely. Inhalation or ingestion of contamination is also possible but even less likely. Heavy contamination is extremely unlikely and would be detected quickly and easily on site; most of it would be removed with the outer clothing and from skin or wounds by simple washing or swabbing.

The dose to ambulance or hospital staff from handling such a casualty is minimal. Even if substantial external contamination is present the radiation dose to attendants is very small and can be disregarded if life-threatening physical injuries call for immediate hospitalisation. Such casualties should be taken to the nearest casualty department rather than risk the extra journey time to a hospital specially nominated to receive irradiated patients. Since radiation is an unfamiliar hazard to ambulance and hospital staff, misunderstanding and undue anxiety may arise and senior medical staff should be prepared to provide information and reassurance. It is important that they have confidence that the radiation exposure which they could receive from contamination is relatively trivial and should not divert attention from the prompt and effective treatment of a casualty. Regular visits to nuclear stations by ambulance crews either in practice or, occasionally, for real non-nuclear incidents, have greatly improved the liaison and understanding between the sites and the ambulance services.

Exposure to whole body doses of radiation in excess of 500 mSv (50 rem) places the exposed person at risk of developing radiation sickness, although most people will escape serious effects unless a substantially higher dose (about five times as much) is received. Small numbers of such exposures, probably isolated cases, could conceivably result from either a major accident at a nuclear site or from the serious mishandling of a radioactive source. Treatment of acute radiation sickness requires the special facilities of a sterile environment, bone marrow transplantation etc. and these are available at the Royal Marsden Hospital Special Unit at Sutton in Surrey. Historically, the CEGB has made arrangements for any employee at risk of acute radiation sickness to be transferred to this hospital for treatment if necessary. There are now many more district general hospitals which are equipped to accept such cases, where even marrow transplantation can be performed. Therefore there is less dependence on such centres as the Royal Marsden. The preparedness of district general hospitals to receive nuclear emergencies is constantly changing. This requires that the CEGB should continually update its procedures and its emergency handbook so that the latest available information is known to the responsible Medical Officer.

Should there be a risk of internal contamination various prophylactic preparations are kept on site. Potassium iodate tablets will be used on the advice of the site emergency controller depending upon the levels of ^{131}I. Provision is also made for the issue of these tablets to members of the public by the police under the direction of the site emergency controller, if there is any risk that members of the public at large could have inhaled or ingested radioactive iodine. Although iodate tablets are available and will be administered when required, such a simple procedure is not without its problems. The tablets have to be stored, hopefully forever, without being required. In some areas there is reluctance by the police to be responsible for the issue of tablets and, perhaps most serious of all, there is a misconception by some members of the public that taking the tablets will protect them from all the consequences of radioactive fallout. Other preparations are available on site in the event of an intake of radioactive material. These include Gaviscon granules, which are an antacid containing aluminium combined with alginates, which reduce the intake of strontium 90. Calcium DTPA, which is a chelating agent, can be given in the event of an intake of plutonium 239.

Arrangements are made to obtain biological samples from potentially internally irradiated casualties and, depending upon the general condition of the casualty, urine is collected for the first 24 h for assessment by the Health Physics Department. Casualties with excessive radiation exposure are required to have blood samples taken in order to perform white-cell counts and assess

1987, *The British Journal of Radiology*, *60*, 1182–1188

chromosome changes and, if necessary, perform tissue typing.

All of these procedures are laid down in the Handbook for Medical Personnel, copies of which are held by all medical officers, nurses and first-aiders as well as local health authorities, hospitals, in some cases general practitioners, ambulance stations, and any officer in the region of a nuclear power station who could have a need for it. A master list of holders of the Handbook is kept and is updated regularly. In the emergency situation it is also the responsibility of the medical officers of the CEGB to ensure that all necessary information is available and fed to the appropriate authorities.

Compared with the potential casualties from a train or plane crash, a disaster at sea or even a motorway pile-up, an accident at a UK nuclear power plant is most unlikely to produce more than a handful of casualties. Plans are based on a reference accident, a hypothetical even of low probability, for example plant failure leading to the escape of radioactive material such as hot carbon dioxide gas, which could result in a number (less than five) of physically injured casualties who might be contaminated. These would all be site staff. This provides a reasonable scenario on which to base emergency plans. Furthermore, if the principles are right for such a moderate accident then they will operate just as well for a larger disaster, even though it is considered that just such an event is outside any reasonable bounds of possibility.

There is an understandable public misconception about nuclear safety which has clearly not been helped by the events of April 1986, but it should not be forgotten that in this country not a single life has been lost as a result of a nuclear accident at a power station. While that should not lull us into a state of complacency, it should reassure everyone that our operating safety record is excellent and the public must be so educated that, with a better understanding, they may appreciate the real safety of nuclear power. Nevertheless, a good driver anticipates the unexpected and in planning for possible emergencies at nuclear stations that is exactly what has been done. But accidents never happen according to the book and Dwight D. Eisenhower's comment before the Normandy landing is appropriate: "planning is essential, plans are useless". Bearing in mind that caveat, I am convinced that the nuclear power industry is as well prepared for a nuclear accident as it possibly could be.

Reactor accidents in perspective*

By Roger H. Clarke, B.Sc., M.Sc., Ph.D.

National Radiological Protection Board, Chilton, Didcot, Oxon

(*Received February 1987*)

When uranium fuel undergoes fission in a nuclear reactor, the heavy uranium nucleus divides into two non-equal parts called "fission products". These fission products are formed with considerable kinetic energy and loose this energy by collision (slowing down) with other uranium atoms in the fuel lattice. These collisions generate the heat which is removed from the central "core" of the reactor by a coolant material (usually gas or water) which is then used to raise steam to rotate turbines, thus producing electricity.

The fission products formed are statistically distributed amongst a range of elements, from zinc through strontium and iodine to barium and cerium. For each of these elements there are formed a varying number of radioisotopes having radioactive half-lives from fractions of a second to tens of years and occasionally more. The actual quantity of each of these radioisotopes that will be present in a nuclear reactor at any point in time is determined by the yield of that radioisotope per fission event, the power level of the reactor (*i.e.* the fission rate) and the length of time for which the fuel has been irradiated.

The fuel cycle in a modern reactor will normally have the uranium fuel in the core for several years. During this time, long-lived fission products such as caesium 137, with a half-life of 30 years, build up linearly with fuel irradiation. In comparison, the shorter-lived radionuclides such as iodine 131, with an 8-day half-life, achieve an equilibrium level in a few weeks that is proportional to the power level (fission rate). Thus the radionuclides available for release in an accident situation will depend upon the operating state of the reactor: the power rating of the fuel, the time spent in the core, and whether the reactor had been operating at full power for a time or had recently been started up after a shutdown.

---

*© Crown copyright 1987.

Although there will be a wide range of radionuclides, related to the operational history, available for release, the actual quantities which may be released from the fuel in an accident sequence will depend upon the temperatures to which the fuel is raised and on the chemical species of the fission products—their volatility. If the cans which contain the fuel burst, then the first fission products to be released will be the isotopes of the gaseous elements krypton and xenon. These will be followed by the volatile fission products (iodine and tellurium) likely to be released at about one tenth of the rate of the noble gases, then the mid-volatiles (ruthenium and caesium) at a rate of about one hundredth of that of the noble gases, and finally the non-volatiles (barium, cerium, actinides) at about one thousandth of the rate of the noble gases.

These figures are only broad indications and the particular temperatures in an accident sequence will modify them. An explosive disruptive event may lead to fuel vaporisation in which case the full spectrum of radionuclides in the fuel will be released. In any event the quantities of radionuclides which emerge into the atmosphere will depend on the plate-out of the various elemental species on surfaces over which they pass in their pathway from core to atmosphere.

Different accident sequences thus lead to differing radionuclides being released to atmosphere. It is very difficult to predict in advance exactly what may be the primary nuclide of radiological concern and in preparing plans to deal with reactor accidents it is necessary to consider that a wide range of radionuclides may be important and there will be different pathways of exposure: external irradiation from the plume, inhalation of activity from the plume, external dose from ground deposits of activity, and consumption of contaminated foodstuffs.

This will be illustrated by comparing the consequences of the accidents at Windscale in 1957, Three Mile Island in 1979 and Chernobyl in 1986. The consequences will be put into perspective by comparing both the doses with other doses to which the public are exposed in everyday life, and the presumed health effects with the normal risks of life.

THE WINDSCALE ACCIDENT, 1957

Cause and radionuclides released

The fire at Windscale No. 1 pile in October 1957 is described in the report of the Committee of Inquiry (Atomic Energy Office, 1957). The Windscale piles were air-cooled graphite-moderated uranium metal-fuelled reactors for the production of the plutonium required for the atomic bomb programme. At the operating temperatures of those reactors, the neutrons being thermalised (or slowed down) in the graphite caused lattice deformations (interstitials) which meant that energy was stored in the graphite matrix, which could spontaneously relax leading to dangerous overheating. This so-called Wigner energy was therefore released by controlled heating of the graphite periodically to restore the normal graphite lattice.

TABLE I

ESTIMATES OF RADIONUCLIDES RELEASED FROM THE 1957 WINDSCALE ACCIDENT*

Nuclide	Half-life	Quantity released (TBq)	Ratio relative to ^{131}I
^{89}Sr	50 days	3	0.004
^{90}Sr	29 years	0.07	0.0001
^{106}Ru	368 days	3	0.004
^{131}I	8 days	740	1.0
^{132}Te	78 hours	440	0.59
^{133}Xe	5.2 days	12 000	16
^{137}Cs	30 years	22	0.03
^{210}Po	138 days	8.8	0.012
^{239}Pu	24 000 years	0.0016	0.000 002

*From Crick & Linsley, 1982, 1983.

Because of the failure of key instrumentation, which had been subject to maintenance the day before the accident, the operators mistakenly thought the core was cooling without releasing all of the stored Wigner energy. They applied a second period of "nuclear heating" which overheated several fuel channels, leading to uranium oxidation and a spreading graphite fire which eventually involved some 150 channels of fuel. After several unsuccessful attempts to put out the fire, it was finally extinguished by flooding the pile with large volumes of water.

The pile was air cooled on a once-through basis so that the fission products released from the oxidising fuel were carried through the core with the coolant air and discharged up a 120 m chimney. Estimates of the quantities of radionuclides released have been made by Loutit et al (1960), based mainly on measurements of the contamination in environmental materials, and by Clarke (1974) using a computer code to model the fission-product inventory of the core. More recently, Crick and Linsley (1983) gave estimates of the release of non-fission product nuclides that were present in the core, notably polonium 210 which was being produced by neutron irradiation of bismuth ingots in the core. The quantities thought to be released of the nuclides of radiological significance are given in Table I.

Dosimetric consequences

At the time of the accident, the nuclide identified as being of principal concern was iodine 131, and its route to the population was through consumption of cows' milk, grazing animals effectively integrating the deposition of iodine 131 over large areas. Because the release took place from a tall stack, the maximum concentration of iodine 131 was some 3 km downwind from Windscale. Even when account is taken of the contribution from inhalation of polonium 210, Crick and Linsley (1983) still conclude that the majority of the dose received arose from iodine 131 and that the milk

TABLE II

Estimates of the effective dose equivalent at the area of maximum deposition of ^{131}I (mSv)

	Age at time of accident (years)		
	Adult	Child	Infant
Excluding ^{210}Po			
No milk ban	3.8	8.0	20
With milk ban	2.1	3.4	4.3
Including ^{210}Po			
No milk ban	5.7	11	22
With milk ban	4.0	6.4	6.2

ban which was introduced reduced effective dose equivalents to the potentially highest exposed infants by a factor of about four and, for other age groups, by lesser factors.

This is shown in Table II where it can be seen that the contribution to individual effective doses from polonium 210 is approximately 2 mSv, which is equivalent to the annual effective dose in the UK from natural background radiation. The maximum measured activity in a child's thyroid after the accident is reported at 160 mSv (Atomic Energy Office, 1957) which corresponds to an effective dose equivalent of 4.8 mSv, which, when allowance is made for contributions from other nuclides and pathways, gives a maximum individual effective dose of about 9 mSv.

Table III gives the collective effective dose equivalent commitments from the accident. The total impact is estimated at 2000 man-Sv mainly over central and southern UK. Of this total some 30% is due to inhalation of the quantity of polonium 210 now thought to have been released. Of the remainder, about half was due to iodine 131 in milk, the other half being contributed equally by inhalation of iodine 131 from the plume and by external irradiation from caesium 137 deposited onto the ground.

TABLE III

Collective effective dose equivalent commitment (man-Sv) due to the Windscale 1957 fire*

Pathway	Cumbria	UK	UK and continent
Inhalation	35	900	980
Ingestion			
milk	88	570	590
other foods	12	170	190
External			
ground deposit	12	190	210
plume	5	54	57
Total (rounded)	150	1900	2000

*From Crick & Linsley, 1983.

Health effects

The highest organ irradiation was to the thyroid and the expected health effect would be an increase in the risk of cancer; a few per cent of those induced by radiation are thought to be fatal, the majority being non-fatal although requiring treatment. The appearance of any cancers would be over a few decades after irradiation. For a standardised population, the time integrated risk of thyroid cancer is thought to be about 10^{-2} Sv^{-1}, of which 5% may be fatal.

The lifetime risk of radiation-induced thyroid cancer in the most exposed individuals may be estimated at 1/1000. These risks are for the few infants measured who were estimated to receive thyroid doses of about 100 mSv; for adults with the highest doses, the risks are about a factor of five less. The highest *annual* risk thus corresponds to about 2/100 000 per year. The natural risk of thyroid cancer in 15–25-year-olds is about 2/1 000 000 per year for males and 8/1 000 000 per year for females which increases throughout life.

Although the risks to those who were infants in 1957 are up to 10 times the natural incidence, so few children were involved at these doses that it is unlikely that any excess cases will be observed.

The collective effective dose equivalent commitment for the accident in the UK can be used to predict a number of cancer deaths. However, at the very low levels of individual dose involved, it must be questionable as to whether the risks are real. They can only be regarded as an upper estimate and the most likely number of health effects will be lower and may be zero. Using standard International Commission on Radiological Protection (ICRP) risk factors, Crick and Linsley (1983) estimate the impact on the UK population over 40 years could be 33 health effects. These would be mostly fatal cancers with some hereditary defects. The total number of thyroid cancers would be 260, 13 of which would be fatal. An incidence of 6.5 thyroid cancers a year over 40 years in the whole of the UK, if real, may be compared to a natural incidence in England and Wales of between 600 and 700 per year (25% males, 75% females) based on figures from the Office of Population Censuses and Surveys (1975).

Since the thyroids of members of the UK population are also subject to background radiation of about 1 mSv each year, the effects of the Windscale accident, which gave only a few days equivalent of background radiation over most of England and Wales, are unlikely to be seen. Even the effect of the release of polonium 210 was only equivalent to about 10% of the *annual* exposure of the population to naturally occurring polonium 210. It seems unlikely therefore that any effects will be seen which can be attributed to the Windscale accident.

The Three Mile Island Accident, 1979

Cause and radionuclides released

The accident at Three Mile Island has been the subject of many reports, particularly those of the

United States Nuclear Regulatory Commission (1980) and the President's Commission (1979). The basis of the accident was straightforward but the details were extremely complicated. The reactor was of a pressurised water (PWR) design where water under high pressure cools the core, without boiling, and passes through boilers raising steam to the turbine. The pumps providing feedwater to the boilers failed, and the automatic safety system shut down the turbine. This meant that heat was not removed from the reactor primary circuit, that water became hotter and the pressure rose. The reactor's safety system shut it down automatically and a pressure relief valve correctly opened to let water out of the primary circuit to reduce the pressure. That relief valve failed to close when the primary circuit pressure fell, although the control-room instrumentation indicated closure. As the primary circuit pressure fell, high-pressure emergency core cooling water was automatically injected but was manually stopped by the operators in the mistaken belief that the reactor was full of water, due to instruments giving false readings because of steam generation in the core. At this point severe damage to the uncooled fuel occurred.

Steam and water left the reactor through the open relief valve, but the volume of water was greater than the capacity of the tank into which it drained, rupturing sealing discs and allowing some 1 100 000 litres of water to flood the reactor sump and basement. Now fission products could be transported from the primary circuit and large amounts of fission products in water were released into the auxiliary building. No longer held under pressure, krypton and xenon and other volatile fission products evolved from the water to the auxiliary building air and thence to atmosphere.

Recent comprehensive estimates of the releases of radionuclides from Three Mile Island have been given by Behling and Hildebrand (1986) and the more important figures are given in Table IV. The quantity of iodine 131 release was nearly 1000 times less than in the Windscale accident although that of xenon 133 was 25 times greater. In comparison with noble gases, far less caesium, strontium and iodine were released from Three Mile Island than from Windscale because of the tortuous pathway from the core to atmosphere and, because the containment system was intact, the air inside the buildings was released through the normal filtration system.

TABLE IV

MAJOR RADIONUCLIDE RELEASES ESTIMATED FOR THE 1979 THREE MILE ISLAND ACCIDENT

Nuclide	Half-life	Quantity released (TBq)
^{88}Kr	2.8 hours	2257
^{89}Sr	50 days	0.000 000 2
^{90}Sr	29 years	0.000 000 2
^{131}I	8 days	1
^{133}Xe	5.2 days	307 100
^{135}Xe	9.1 hours	55 500
^{137}Cs	30 years	0.000 001

Dosimetric consequences

The principal pathway of exposure of the public was external radiation from the radioactive decays of the noble gases in the plume as it dispersed. The noble gases are chemically and biologically non-reactive. Monitoring off-site has confirmed this result and the maximum individual off-site dose from external γ rays has been estimated at 0.83 mSv on the basis of TLD detectors at 0.5 miles from the site. No member of the public could have been closer to the site (President's Commission, 1979; US Nuclear Regulatory Commission, 1980; Behling & Hildebrand, 1986).

The average dose to those individuals within 10 miles of the site has been estimated at 0.08 mSv effective dose equivalent. The highest individual thyroid dose is less than 0.2 mSv, the collective thyroid dose equivalent commitment is between 14 and 28 man-Sv out to 50 miles and the collective effective dose equivalent commitment between 16 and 53 man-Sv, with a most probable value of 33 man-Sv within 50 miles. The total collective effective dose equivalent containment is estimated by UNSCEAR (1982) to be about twice the 50-mile values.

Although the total quantity of activity released from Three Mile Island is much greater than from Windscale, the dosimetric consequences are far less (by a factor of 10) because of the different radionuclides and therefore pathways of exposure involved.

Health effects

Based on the highest individual effective dose of 0.8 mSv, the risk to such an individual is highly speculative but, if linearity is assumed, it will correspond to 1/100 000 over the next few decades or perhaps 2/10 000 000 per year. Estimates of the numbers of health effects in the 2 000 000 people within 50 miles have been given as less than one fatal cancer among 325 000 fatal cancers that will occur in that population, less than one non-fatal cancer among 216 000 that will occur in that population and less than one genetic defect among 78 000 expected from the offspring of that population (Behling & Hildebrand, 1986). If the whole population of the USA is considered, the number of theoretical cancers from Three Mile Island does not change, but the expected naturally occurring numbers increase by a factor of about 100.

There have been many claims of acute adverse health effects in the population around Three Mile Island. They include complaints of metallic taste, disruption of menstrual cycle, burning watery eyes, respiratory inflammation, erythema and skin disorders, nausea and vomiting, diarrhoea, organ collapse (lungs, spleen, kidney and heart) and heart dysfunction (tachycardia and aortic valve defect). None of these have been substantial and claims by local citizens that excess cancers are occurring around the site have been criticised by professional epidemiologists.

THE CHERNOBYL ACCIDENT, 1986

Cause and radionuclides released

The cause and consequences of the accident have been reviewed by an international nuclear safety advisory group of the International Atomic Energy Agency (1986). The RBMK reactor at Chernobyl unit 4 was one of 15 brought into operation in the USSR and is a graphite-moderated reactor cooled by water in pressure tubes surrounding each fuel element. The water boils in the upper part of the vertical tubes to produce steam which is fed directly to turbines to generate electricity.

The accident occurred when tests were being carried out to see if the generators, during an electrical power failure, could supply sufficient electrical energy for a short period until the standby diesel generators could start supplying emergency power. The reactor was run down by the operators to a steady lower power, a regime forbidden by the operating instructions because coolant flow rate and cooling conditions could not be stabilised and the reactor design meant it became more reactive. At the same time the operators deliberately, and in violation of rules, withdrew most control and safety rods from the core and switched off their automatic shutdown systems.

The operators reduced the flow of water through the core leading to steam voids which, in the design, made the reactor produce more power, for which there was insufficient cooling. But automatic safety shutdown systems had been made inoperative and the continuous input of power meant that the reactor eventually went super prompt critical and achieved 100 times normal full power within 4 s. The energy released by the power excursion ruptured fuel and caused a steam explosion which shifted the 1000-tonne reactor cover plate and resulted in all cooling channels being cut off. After 2 or 3 s, a second explosion (possibly hydrogen) occurred and hot pieces of fuel were ejected directly from the destroyed reactor building. The graphite, now open to the air, caught fire and the release of radionuclides continued over 10 days.

The nuclides now thought to have been released are shown in Table V. There was a total release of noble gases; the release of iodine was about 20% of that available in the core, that of caesium about 10% while about 3% of the rare earths and actinides were released. Some 3–4% of the core is believed to have been ejected to the atmosphere, of which some 0.3–0.5% was deposited on the site and some 1.5–2% was deposited within 20 km, leaving about 1–1.5% of the core dispersed beyond 20 km.

TABLE V

ESTIMATES OF RADIONUCLIDES RELEASED FROM THE 1986 CHERNOBYL ACCIDENT

Nuclide	Half-life	Quantity released (TBq)	Amount relative to ^{131}I
^{85}Kr	10.7 years	33 000	0.12
^{89}Sr	50 days	80 000	0.31
^{90}Sr	29 years	8000	0.03
^{99}Mo	66 hours	110 000	0.42
^{95}Zr	64 days	140 000	0.54
^{103}Ru	39 days	119 000	0.46
^{106}Ru	368 days	58 000	0.22
^{131}I	8 days	260 000	1.0
^{132}Te	78 hours	48 000	0.18
^{133}Xe	5.2 days	1 700 000	6.5
^{134}Cs	2 years	19 000	0.07
^{137}Cs	30 years	38 000	0.15
^{144}Ce	284 days	89 600	0.34
^{238}Pu	88 years	30	0.0001
^{239}Pu	24 000 year	25	0.0001
^{240}Pu	6500 years	36	0.0001
^{241}Pu	14.4 years	5100	0.02
^{242}Cm	163 days	780	0.003

Dose distributions

The Soviet authorities have reported that acute radiation syndrome of varying clinical severity was diagnosed in 203 subjects who were all workers involved on the site. The doses were principally due to external irradiation by β and γ rays and were in the range of 2–16 Gy. A complication in the treatment of these patients was the development in 48 individuals of severe skin burns covering up to 90% of the body from aerosols deposited on the surface of the skin and clothes. None of the 135 000 members of the public evacuated from the 30 km zone around Chernobyl was diagnosed as exhibiting acute radiation syndrome. All were promptly medically examined.

The highest contributions to dose came from iodine 131 in milk and from caesium 137 ingested in foodstuffs and externally from its deposition on the ground. The external radiation doses to most of those evacuated were less than 250 mSv, although a few in the most contaminated areas might have received doses up to 300–400 mSv. The collective dose from external radiation to the 135 000 is estimated at 16 000 man-Sv. Individual children's thyroid doses may have been as high as 2.5 Sv although the average thyroid dose is 300 mSv and a collective thyroid dose of 40 000 man-Sv adding 1200 man-Sv to the collective effective dose equivalent.

The collective doses in various regions of Europe and the Soviet Union are shown in Table VI. The Soviet authorities have estimated 2 000 000 man-Sv in the European Soviet Union and the nuclide which has contributed most of the dose is caesium 137. The collective effective dose over all time to the members of the European Community has been estimated at 80 000 man-Sv (Morrey et al, 1987) and the collective dose to the whole of Europe outside the USSR is likely to be about twice this value. The collective thyroid dose

TABLE VI

Collective doses from the Chernobyl reactor accident

Area	Population	Collective effective dose equivalent commitment (man-Sv)
Evacuated	135 000	17 000
European Soviet Union	75 000 000	2 000 000
European Community	300 000 000	80 000
UK	55 000 000	3000

within the European Community is about 180 000 man-Sv, making a contribution of 5400 man-Sv to the collective effective dose. Within the European Community the biggest contributions to collective dose are from the Federal Republic of Germany at 30 000 man-Sv and from Italy at 26 000 man-Sv. The UK contribution was 3000 man-Sv, with 330 man-Sv being the contribution to collective effective dose equivalent from thyroid irradiation. In Europe the collective effective dose from the Chernobyl accident integrated over all time is about 16% of the *annual* collective effective dose from natural background radiation.

The main pathways contributing to the collective dose in Western Europe are the consumption of contaminated foodstuffs and external radiation from deposited material. In the first year food consumption is the dominant pathway but in later years external radiation from deposited material increases in importance. For both pathways, caesium 137 is the most important nuclide.

Health effects

A complete assessment of the health detriment due to Chernobyl is still tentative at present because it is unclear what the longer-term doses will actually be within the Soviet Union. They will depend on the transfer of caesium 137 through the environment and the use made of the land agriculture and habitation. International Atomic Energy Agency (IAEA) experts estimate that the Soviet estimate of collective dose could be too high by a factor of 10 (IAEA, 1986). However, tentative estimates can be made for numbers of health effects on the basis of reported collective doses. At very low levels of individual dose it is not clear that the risk is real, but calculations are performed on the prudent assumption that there is a linear non-threshold dose–response.

For the 135 000 evacuees who received high doses, the collective whole-body dose is estimated at 1.6×10^4 man-Sv and should lead, on the basis of present risk estimates, to 160 late fatal cancers. The contribution from doses to the thyroid from iodine 131 would increase this estimate. If the average dose to the thyroids of those evacuated was 300 mSv (IAEA, 1986) then the collective dose would be about 40 000 man-Sv, adding about 1200 man-Sv to the effective dose equivalent and leading to perhaps 10 fatal thyroid cancers and a substantially higher number of non-fatal cases.

To put these estimates in perspective it has to be remembered that the cancers would appear over the next 40 years or so and about 20% of those evacuated would be expected to die of cancer, based on Western cancer statistics, *i.e.* some 27 000. The estimated extra 170 fatalities would constitute about 0.6% of the spontaneous cases and would be difficult to identify in an epidemiological study, if our present risk estimates are correct.

Even in that part of the population in the European Soviet Union, with a population of 75 million and accepting the Soviet estimate of 2 000 000 man-Sv, the increase in cancer mortality from external irradiation and internal exposure would be about 0.03–0.15% of the natural value. Only in the cohorts with individual doses of about 0.1 Gy is it estimated that individual risks of leukaemia and benign and malignant thyroid neoplasms would be sufficiently increased so as to be detected by epidemiological survey (IAEA, 1986).

Within Europe about 2000 theoretical thyroid cancers would be predicted over the next few decades, if the risks are real at the levels of dose involved and 5% of those are expected to be fatal. The number of thyroid cancers expected in the European Community over the next 30–50 years is about 200 000. The number of theoretical fatalities from all cancers due to Chernobyl in Europe is predicted to be in the region of 1000, spread out over a few decades following the accident. Over the same period about 20 million or so people are expected to die in European Community countries from cancer of one type or another. Again, the effects of Chernobyl are unlikely to be seen in any epidemiological study undertaken in Europe.

Conclusions

In each of the three major reactor accidents which have led to significant releases to the environment, the reactor has been essentially destroyed—certainly Windscale and Chernobyl reactors will never operate and the cleanup operation for Three Mile Island is currently estimated to have cost in excess of US$500 000 000. In each of the three accidents there has not been any fatality *off site* in the short term and any long-term health detriment is unlikely to be seen in comparison with the natural cancer incidence rate. At Chernobyl, early fatalities did occur amongst those concerned with fighting the incident on site and late effects are to be expected.

However, despite the severe nature of the accidents, their impact on the public was largely one of perceived and not real risk. For example, over most of England the dose incurred was about equivalent to that of flying to Spain and back in a jet aircraft—even in most affected areas, doses were little different to a long haul jet flight where the reduction in atmospheric shielding increases whole-body exposure.

Therefore, a major lesson is that better communication with the public is required. There is a need to explain why people are expected to continue living normally in any enhanced artificial radioactive environment; although the dose may be very small, activity is measurable and causes concern. The fact that in radiological protection we assume a linear non-threshold response means that there is no level of zero risk and the problem to be faced is to argue for the acceptability of the presumed risk.

Thus, we found on the one hand statements that there was no health risk to any individual—on the basis that a 1/1 000 000 risk is really insignificant—yet, on the other hand, since 50 000 000 people were involved in the UK, theoretically 50 cancers result. It proved almost impossible to explain this to the public, or at least to the media.

The public has to be made more aware of radiation in their environment, its risks and the methods used to control it. This needs to be a planned campaign and the presentation of the concepts of radiological protection must be greatly simplified before any attempt is made to put them to the public.

REFERENCES

Atomic Energy Office, 1957. *Accident at Windscale No. 1 Pile on 10 October, 1957.* Cmnd 302, (HMSO, London).

Behling, U. H. & Hildebrand, J. E., 1986. *Radiation and Health Effects: a Report on the TMI-2 Accident and Related Health Studies.* GPU Nuclear Corporation Middleton, PA17057, USA.

Clarke, R. H., 1974. An analysis of the 1957 Windscale accident using the WEERIE code. *Annals of Nuclear Science and Engineering, 1,* 73–82.

Crick, M. J. & Linsley, G. S., 1982. *An Assessment of the Radiological Impact of the Windscale Reactor Fire October 1957.* National Radiological Protection Board Report R135 (HMSO, London).

Crick, M. J. & Linsley, G. S., 1983. *Addendum to Report NRPB R135.* National Radiological Protection Board (HMSO, London).

International Atomic Energy Agency, 1986. *Summary Report on the Post-accident Review Meeting on the Chernobyl Accident,* Safety Series 75-INSAG-1 (IAEA, Vienna).

Loutit, J. F., Marley, W. G. & Russell, R. S., 1960. *Appendix H to the Hazards to Man of Nuclear and Allied Radiations,* 2nd report to the Medical Research Council, Cmnd 1225 (HMSO, London).

Morrey, M., Brown, J., Williams, J. A., Crick, M. J. & Simmonds, J. R., 1987. *A Preliminary Assessment of the Radiological Impact of the Chernobyl Reactor Accident on the Population of the European Community,* (Health and Safety Directorate, Luxembourg).

Nuclear Regulatory Commission, 1980. *Three Mile Island—a Report to the Commissioners and to the Public,* NUREG/CR-1250, USNRC, Washington.

Office of Population Censuses and Surveys, 1975. *The Registrar General's Statistical Review of England and Wales (1968–70).* Supplement on Cancer (HMSO, London).

President's Commission, 1979. *Report of the President's Commission on the Accident at Three Mile Island, the Need for Change: the Legacy of TMI.* Chairman, J. G. Kemeny (US Government Printing Office, Washington DC).

UNSCEAR, 1982. *Ionising Radiation: Sources and Biological Effects.* Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. 1982 report to the General Assembly, United Nations, New York.

1987, *The British Journal of Radiology*, 60, 1189–1195 DECEMBER 1987

Regression of the radiological changes of Gaucher's disease following bone marrow transplantation

By F. Starer, J. D. Sargent and J. R. Hobbs

Department of Diagnostic Radiology and the Bone Marrow Team, Westminster Children's Hospital, Vincent Square, London SW1P 2NS

(*Received April 1987*)

ABSTRACT

Seven children with Type I Gaucher's disease have been treated with bone marrow transplantation (BMT). One patient died from the complications of BMT. In five patients computed tomography (CT) of the femora showed initially high attenuation in the marrow, returning towards normal after successful BMT. One of these patients also showed clearing of pulmonary infiltrates following treatment. In the first patient in the series no pre-transplant CT measurements were carried out but plain radiographs have demonstrated a return to normal shape of her femora 2½ years after BMT. It is hoped that CT of the marrow cavities may provide a simple, non-invasive method for monitoring progress following BMT.

The radiological changes in the skeleton resulting from adult (Type I) Gaucher's disease are well known and have recently been summarised by Pastakia et al (1986). Rapid deterioration following splenectomy has been described (Rose et al, 1982) and was also observed in three of our patients. As it seemed likely that computed tomography (CT) would detect the infiltration of the bone marrow by the Gaucher cells, we have for several years examined the femora of our patients and shown that the attenuation values of the marrow are increased in this condition. This has also been noted independently by Hermann et al (1986). Moreover, we were able to show a consistent fall in the attenuation values of the marrow cavities in our patients following successful bone marrow transplantation (BMT). There is also early indication of a return towards normal shape of the expanded lower femora in the patient with the longest follow-up after BMT.

Hepatosplenomegaly is a constant feature of Type I Gaucher's disease. Pulmonary involvement is less common (Jackson & Simon, 1965; Schneider et al, 1977) but may also be accentuated by splenectomy, as happened in our one patient with pulmonary changes. Incidentally, splenectomy may also be followed by rapid progression of the hepatic involvement (Goldblatt, 1980, quoted by Rose et al, 1982), renal involvement (Chander et al, 1979) and changes in the central nervous system (Dreborg et al, 1980). Our patient with pulmonary involvement made a satisfactory recovery, both clinically and radiologically, following successful BMT.

Successful treatment of Gaucher's disease has not previously been possible, and consequently regression of the radiological changes of this disease has not previously been described.

CASE REPORTS

Case 1

This female patient presented at the age of 13 years with anaemia, bruising and a massive hard spleen. A year later she had a splenectomy. Soon after this she began to experience bone pains and at 15 years there was radiological evidence of avascular necrosis of the left femoral head; a year later the right femoral head became similarly involved. She had a BMT when aged 16½ years and made an uneventful recovery, with only mild skin graft-versus-host disease. Since then there has been marked reduction in liver size and her growth has gone from the 10th to the 40th centile. Her general condition is excellent. Computed tomography was not performed before the BMT but comparison of plain radiographs of the femora has shown a striking return towards the normal shape 2½ years after the transplant (Fig. 1). The hip changes, however, remain unaltered.

Case 2

This male patient's mother discovered his splenomegaly when he was 18 months old (Fig. 2). At this time, his chest radiograph was normal. The spleen was removed and this was followed by progressive deterioration in his general health.

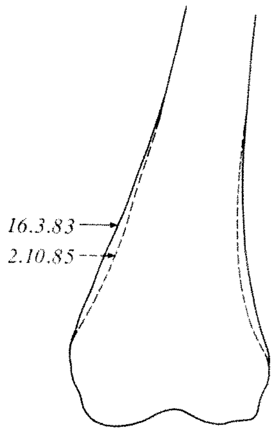


FIG. 1. *Case 1*.

Tracings of outlines of right femur before BMT (16.3.83) and 2½ years later (2.10.85).

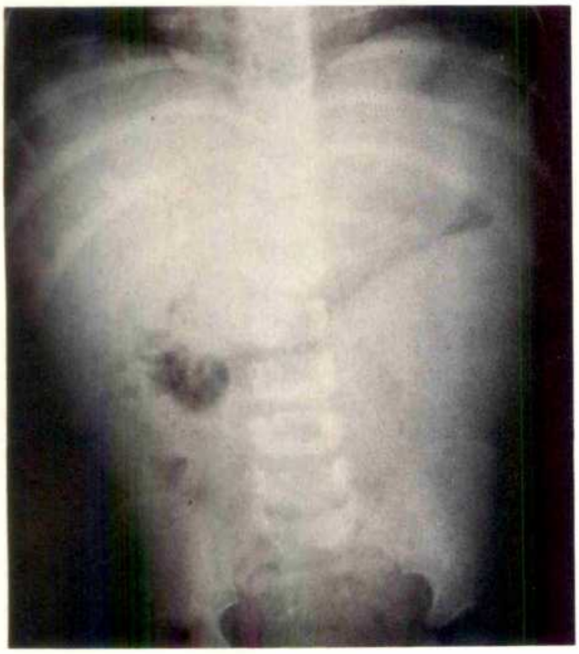


Fig. 2. *Case 2.*

Radiograph of abdomen at 18 months showing marked splenic enlargement.

When 4 years old he complained of pain in the hips, knees and back. When seen at the age of 11½ years, he was dyspnoeic. A chest radiograph showed diffuse pulmonary infiltration and collapse of the bodies of T11 and T12 (Fig. 3) and there were varying degrees of collapse in the lumbar bodies. The liver was greatly enlarged and avascular necrosis was evident in both femoral heads (Fig. 4). There was widening of the lower femora with further evidence of bone infarcts (Fig. 5).

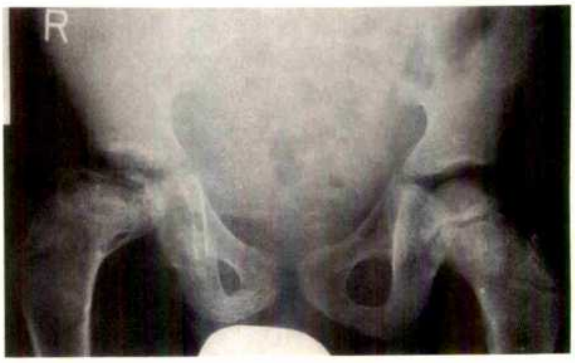


Fig. 4. *Case 2.*

Avascular necrosis of femoral heads and gross hepatomegaly.

When he was 12 years old BMT was performed and this was followed by rapid clinical improvement. After 18 months the pulmonary infiltrate had cleared (Fig. 6) but the spinal changes remain (Fig. 7). He is now active and no longer dyspnoeic and is being considered for corrective surgery to improve the thoracic kyphosis.

Computed tomographic scans of the femora are shown in Figs. 8A, B and C and the attenuation values and enzyme levels have been plotted in Fig. 9.

Case 3

Since the age of 2 years this male patient had been noticed to bruise easily and he subsequently complained of bone pains. He was referred for treatment at the age of 8 years, when he had marked hepatosplenomegaly. Mild skin graft-versus-host reaction and an infected central line followed BMT, as well as prolonged thrombocytopenia due to the splenomegaly. Eventually this settled. There was then marked reduction in the size of the liver and spleen. His height and weight moved from the third to the 10th centile for his age.

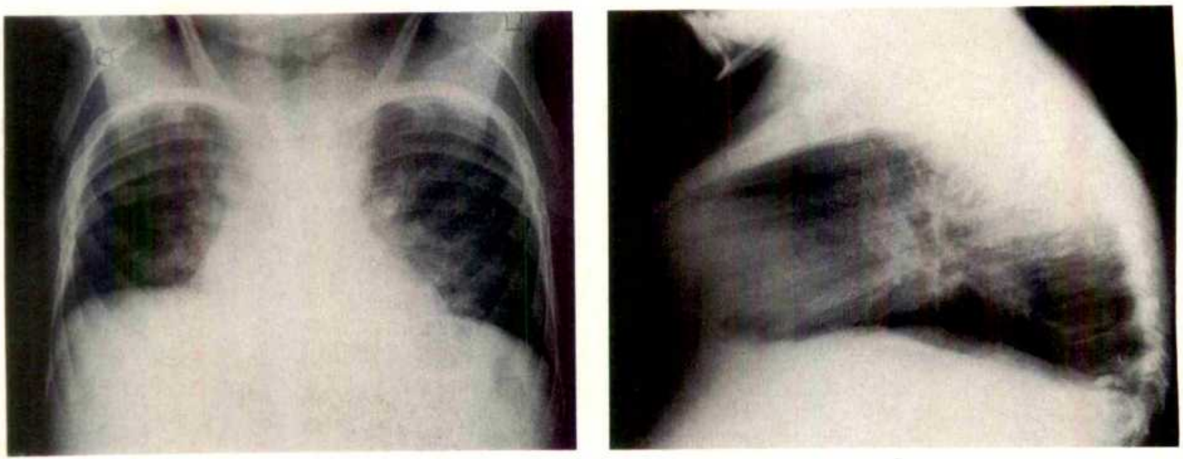

A B

Fig. 3. *Case 2.*

Chest radiographs, (A) postero-anterior and (B) lateral, 9 years after splenectomy, showing diffuse pulmonary infiltration and collapse of bodies of T11 and T12.

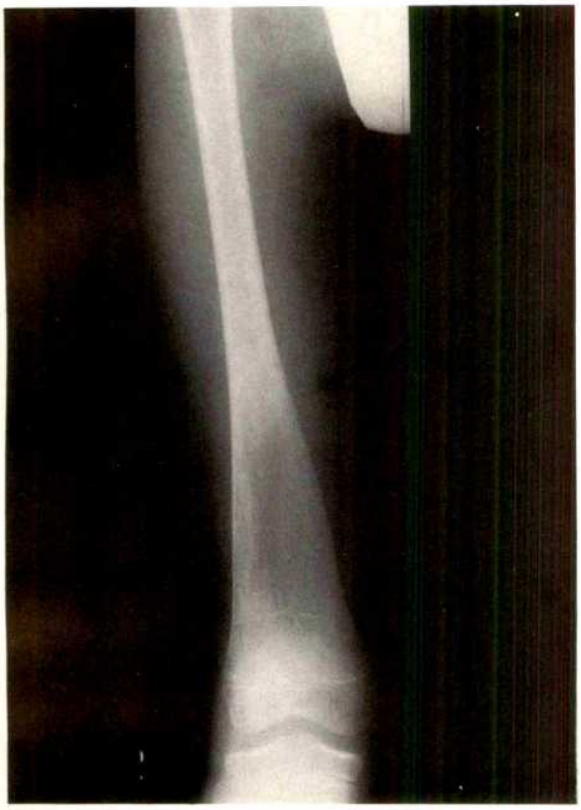


FIG. 5. *Case 2.*
Widening of lower femur.

The changes in marrow attenuation values and enzyme levels before and after BMT are shown in Fig. 10.

Case 4

This girl was found to have gross splenomegaly during investigation for anaemia and a diagnosis of Gaucher's disease was made; BMT was carried out at the age of 6 years. The post-graft period was complicated by an infected central line and thrombocytopenia. There was a poor white-cell response due to hypersplenism and she died of generalised aspergillosis 56 days after the graft.

Case 5

The diagnosis of Gaucher's disease was made in this female patient before her fifth birthday following investigation for recurrent abdominal pain, when gross enlargement of the liver and spleen had been found. She also had a tendency to bleed and thrombocytopenia. An elective splenectomy was carried out shortly before BMT to avoid subsequent problems with thrombocytopenia and neutropenia. The BMT was performed at the age of 5 years and 10 months. There was smooth post-graft recovery and she is alive and well 14 months later. Figure 11 shows the change in marrow attenuation and enzyme levels before and after BMT.

Case 6

This female patient was investigated for hepatosplenomegaly when she was $3\frac{1}{2}$ years old and the diagnosis of Gaucher's disease was made. At 5 years she was found to have collapsed lower thoracic vertebrae. Following splenectomy when she was 7 years old she developed a limp and radiographs a year later showed avascular necrosis of the femoral heads. Bone marrow

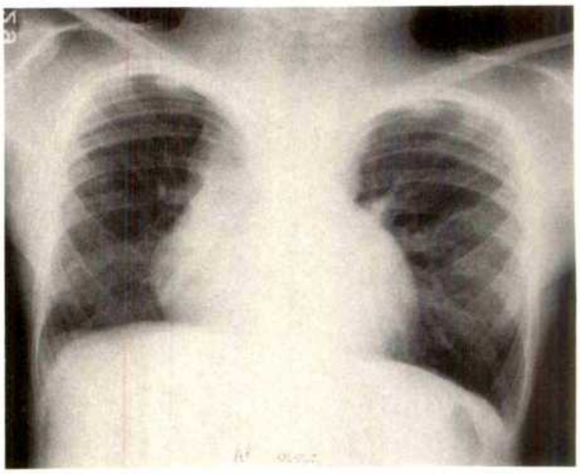


FIG. 6. *Case 2.*
18 months after BMT. The lungs are now clear.

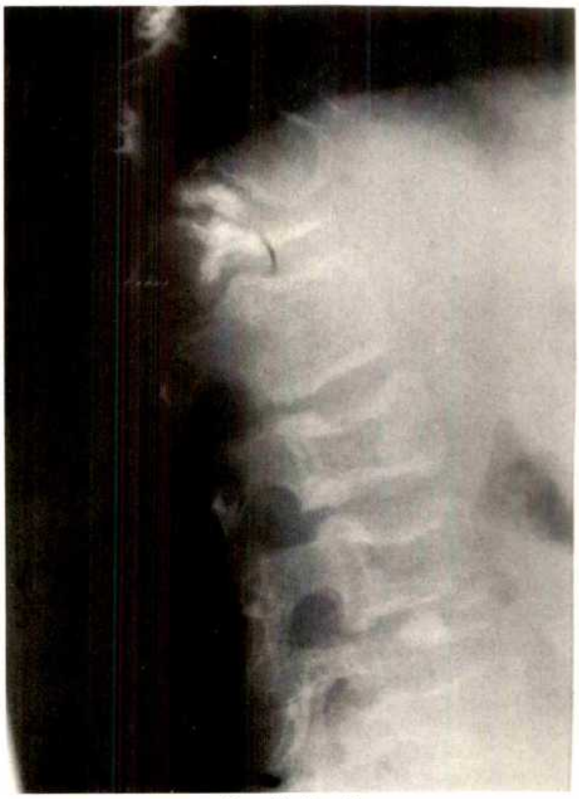


FIG. 7. *Case 2.*
Persistent collapse of vertebrae in the lumbar spine.

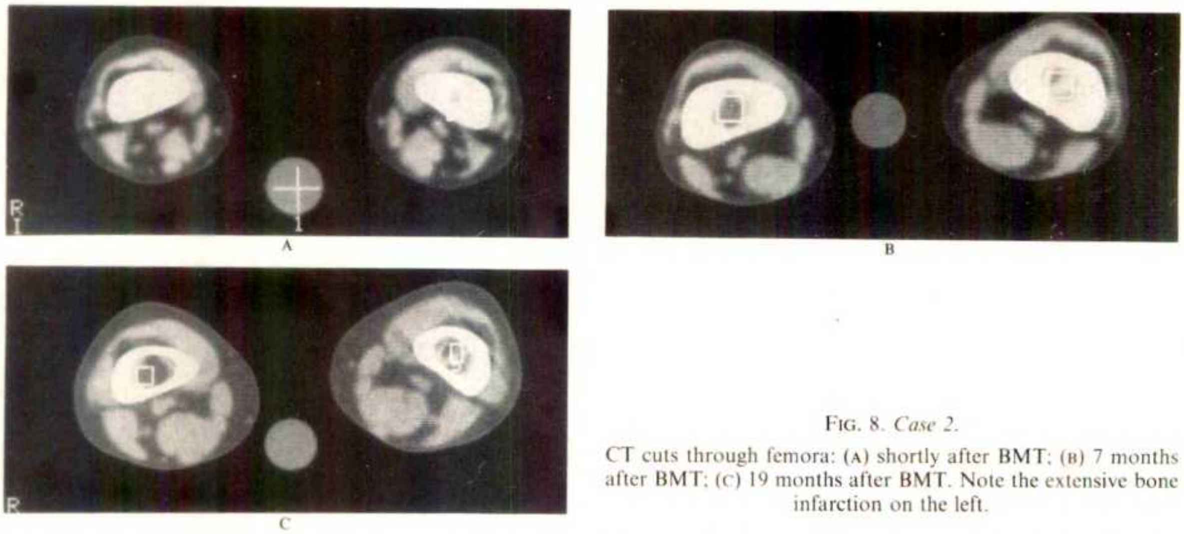


Fig. 8. *Case 2.*

CT cuts through femora: (A) shortly after BMT; (B) 7 months after BMT; (C) 19 months after BMT. Note the extensive bone infarction on the left.

transplantation was performed when she was 13 years old. It was followed by chronic graft-versus-host reaction and persistent hip symptoms but she is well otherwise. Figure 12 shows the change in marrow attenuation and enzyme levels before and after BMT.

Since the graph of marrow densities for this patient was prepared, another CT scan has been carried out almost exactly 1 year after her BMT. The right femoral marrow on this occasion showed an attenuation value of −53 HU and the left was −51 HU.

Case 7

This female child was noted to have a distended abdomen and an enlarged liver and spleen when she was 10 months old. The diagnosis of Gaucher's disease was made following bone marrow aspiration. She received BMT when 2 years old. Following the graft she has been well. Her enzyme level has remained high but her white-cell chromosomes were female although the donor had been male. This suggests that she is at present in a chimeric state. The changes in marrow attenuation values and enzyme levels before and after BMT are shown in Fig. 13.

Methods

In each patient investigated by CT a small number of cuts was obtained through the liver before and after BMT for density measurements. Digitised images of the femora were then recorded and several planes were

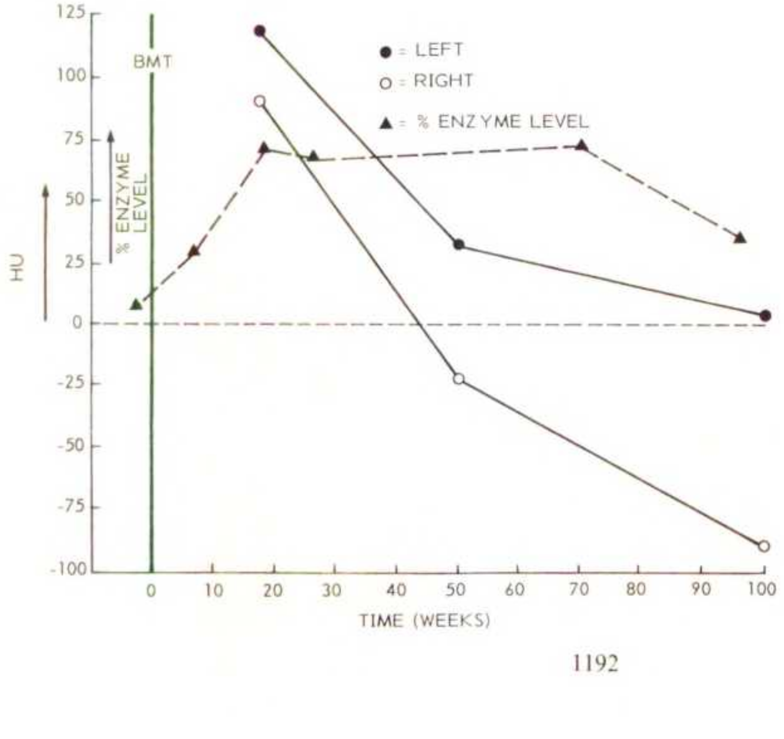


Fig. 9. *Case 2 (age 11 years).*

Graph to show changes in attenuation values and enzyme levels.

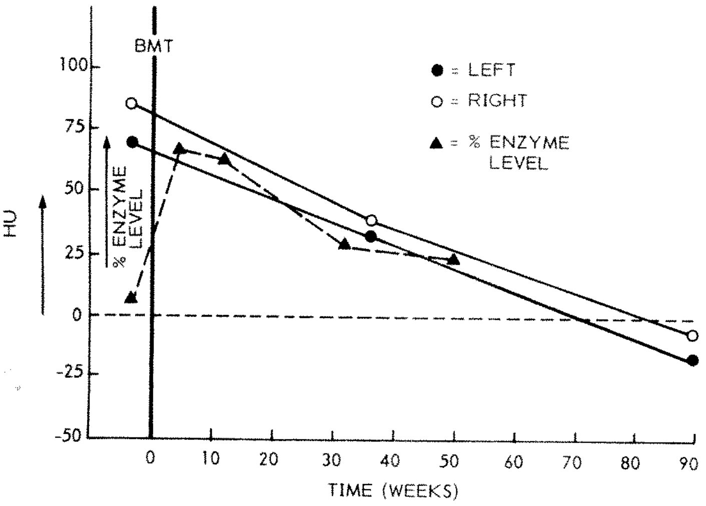


FIG. 10. *Case 3 (age 8 years).*
Graph to show changes in attenuation values and enzyme levels before and after BMT.

chosen. The purpose of this was to try to avoid areas of the femora with obvious bone infarcts and to make it possible to re-scan at the same levels. At each examination a water phantom was placed between the thighs in order to check the calibration of the scanner. Density readings of the phantom were always close to zero, but when necessary the readings have been corrected and expressed in relation to the water phantom. This is permissible since attenuation values are expressed in a linear manner.

Cerebroside β-glucosidase levels are expressed as a percentage of normal. This is obtained by comparing the activity of the patient's serum with a pool derived from 10 normal persons.

DISCUSSION

Gaucher's disease consists of three hereditary disorders in the metabolism of glucosyl ceramide. It falls into the general category of the lipid storage diseases. Deficiency in the enzyme β-glucosidase leads to the accumulation of complex lipids in the reticulo-endothelial cells, which take on a characteristic "wrinkled tissue paper" appearance under light microscopy and are called Gaucher's cells.

The disease is inherited as an autosomal recessive trait. It is arbitrarily divided into three groups, based on the progression of the disease and the organ systems involved. Type I (chronic non-neuropathic) is characterised by slow progression and lack of neuro-

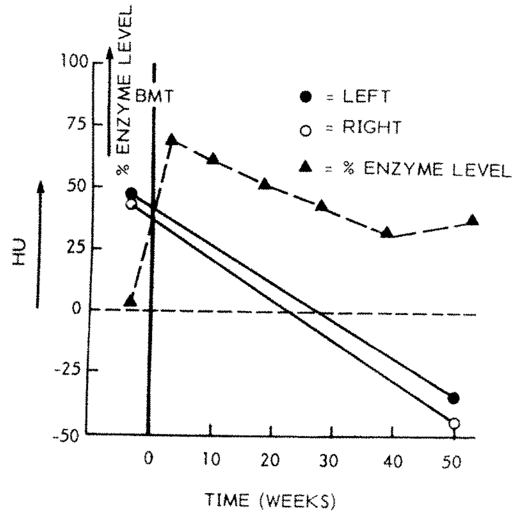


FIG. 11. *Case 5 (age 5 years).*
Graph to show changes in attenuation values and enzyme levels before and after BMT.

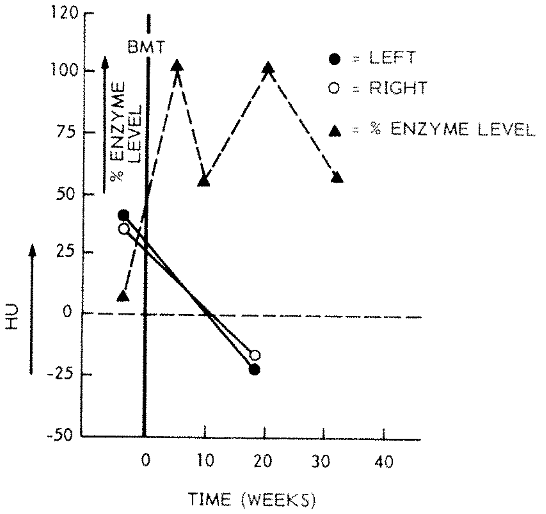


FIG. 12. *Case 6 (age 13 years).*
Graph to show changes in attenuation values and enzyme levels before and after BMT.

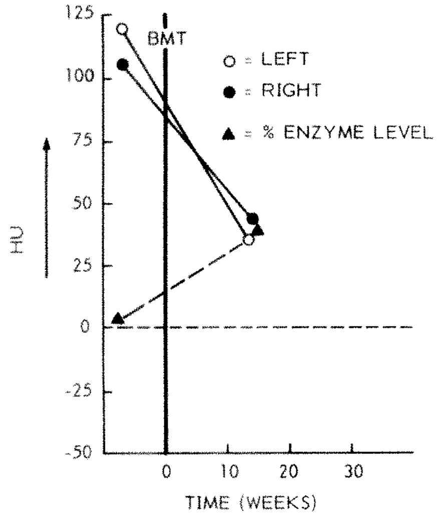


Fig. 13. *Case 7 (age 2 years).*

Graph to show changes in attenuation values and enzyme levels before and after BMT.

logical involvement. Diagnosis is usually made in the first decade because of hepatosplenomegaly. Many patients live to adulthood. Type II (acute neuropathic) is diagnosed in the first months of life; patients show progressive neurological deterioration and die before 2 years of age. Type III (subacute neuropathic) is an intermediate group of patients who show neurological involvement throughout childhood. All forms of Gaucher's disease share the clinical features of hepatosplenomegaly, the presence of Gaucher's cells in the bone marrow and increased levels of serum acid phosphatase.

There is displacement of bone marrow in the skeleton, leading to alteration in the shape of long bones, osteoporosis, periosteal reactions (Strickland, 1958) and bone infarcts. The mechanism leading to bone infarcts is not certain (Pastakia et al, 1986) but the results are bone necrosis and areas of bone sclerosis. Normal bone marrow contains a high fat content and therefore shows negative attenuation values on CT. In our patients, attenuation values in the femora were uniformly raised to positive values. In the series reported by Hermann et al (1986) only one out of 23 patients showed normal attenuation values and even three out of the four patients with normal radiographs had abnormally high values on CT. These authors make the interesting comment that the Gaucher cells are laden with a lipid and should therefore have a negative attenuation coefficient. They suggest that the positive coefficient may be due to intramedullary fibrosis or even calcification. However, trephine biopsies done on our patients before BMT did not show any significant fibrosis or calcification in the marrow. We received the generous gift of a sample of purified glucosyl ceramide, hoping to perform density measurements at different dilutions. Unfortunately, the quantity proved to be too small to provide reproducible results. In this connection, it is worth pointing out that the attenuation values in the livers of our patients were always normal before BMT, although the livers were heavily infiltrated with Gaucher cells, nor did the values change after most of the lipid had been removed following BMT. This would suggest that the attenuation value of the lipid is not greatly different from that of normal liver. This still leaves us unable to explain the much higher attenuation values found in the marrow of some of our patients but it is suggested that there may be diffuse microinfarction which we failed to recognise on plain radiographs.

Bone marrow transplantation supplies a source of the deficient enzyme; it is carried to the tissues by polymorphonuclear leucocytes and seems able to reverse the build-up of glucosyl ceramide. Once the immediate post-BMT problems have been overcome, it has led to a marked improvement in the patient's clinical condition (Hobbs et al, 1984; Hobbs, 1985). It has been satisfying to be able to follow the parallel return to normal of the bone marrow attenuation values. The trend towards normal values has been observed within weeks of the BMT; it is questionable whether fibrosis could resolve quite so quickly. Following BMT there is an initial sharp increase in β-glucosidase level but in most patients this subsequently fell to levels which were low but still higher than the pre-transplant measurements and resorption of Gaucher's lipid proceeded satisfactorily.

Since Gaucher's disease is carried as an autosomal recessive trait, some members of the families involved who are suitable as marrow donors will themselves turn out to be heterozygous. Our results do not suggest that there is any difference whether the donor marrow comes from a homozygous or heterozygous individual. A good tissue match appears to be a much more important consideration. Moreover, we have been unable to show any correlation between the response to BMT and the patient's age, the rapidity of the progress of the disease, or previous splenectomy. Admittedly, however, we have too few patients to be certain on these points.

Like Hermann et al, we have found areas of higher attenuation values to correspond with regions of bone sclerosis, which we have interpreted as bone infarction; this is not confined to the cortex. Measurements through infarcts do not represent the general state of the bone marrow.

In Case 2, attenuation values on the left, before and after BMT, have been persistently higher that those on the right, although they are falling in parallel. Careful examination of the plain radiographs of the femora suggests that there is more infarction in the left femur than in the right.

It is known that there are many factors which influence the measurement of attenuation values and these do not require further discussion. We do not wish to claim absolute accuracy for our numerical measurements but the trends are so consistent and uniform that they must be accepted as indicating a real change. The CT measurements of the marrow have provided interesting information on post-transplant changes and it is hoped that they will be an easy and non-invasive method for further follow-up.

So far we have not observed any changes on plain radiographs, with the exception of Case 1. Two and a half years after BMT the lower femora have become more slender. The change is slight but appears to be quite definite. It will be interesting to see whether, with time, the other patients' femora will return to normal. One can hardly expect any change in the hips involved by bone infarction, but there might possibly be some improvement in the collapsed vertebrae of very young patients, judging by the ability of children to reconstitute collapsed vertebral bodies after compression fractures or after eosinophil granulomas.

Finally, one of the most dramatic changes observed in this series has been the clearing of the pulmonary infiltrate in Case 2. Here, clinical improvement preceded radiological clearing by several months.

ACKNOWLEDGMENTS

We are extremely grateful to Prof. D. Patrick of the Institute of Child Health for supplying a sample of glucosyl ceramide. Dr K. Hugh-Jones has made many valuable suggestions. We also wish to thank the Department of Medical Illustration at Westminster Hospital for preparing the illustrative material.

REFERENCES

CHANDER, P. N., NURSE, H. M. & PIRANI, C. L., 1979. Renal involvement in adult Gaucher's disease after splenectomy. *Archives of Pathology, 103,* 440–445.

DREBORG, S., ERIKSON, A. & HAGBERG, B., 1980. Gaucher's disease—Norrbottian type. *European Journal of Pediatrics, 133,* 107–108.

GOLDBLATT, J., 1980. *Gaucher's Disease in the Ashkenazi Jewish Community in South Africa.* (Thesis, University of Cape Town.) (Quoted by Rose et al, 1982.)

HERMANN, G., GOLDBLATT, J., LEVY, R. N., GOLDSMITH, S. J., DESNICK, R. J. & GRABOWSKI, G. A., 1986. Gaucher's disease type I: assessment of bone involvement by CT and scintigraphy. *American Journal of Roentgenology, 147,* 943–948.

HOBBS, J. R., 1985. Correction of 34 genetic diseases by displacement bone marrow transplantation. *Plasma Therapy and Transfusion Technology, 6,* 221–246.

HOBBS, J. R., HUGH-JONES, K., SHAW, P. & POYNTON, C., 1984. Displacement bone marrow transplantation in adult type I Gaucher's disease. Abstract in *British Paediatric Association Meeting, April.*

JACKSON, D. C. & SIMON G., 1965. Unusual bone and lung changes in a case of Gaucher's disease. *British Medical Journal, 38,* 698–700.

PASTAKIA, B., BROWER, A. C., CHANG, V. H. & BARRANGER, J. A., 1986. Skeletal manifestations of Gaucher's disease. *Seminars in Roentgenology, 21,* 264–274.

ROSE, J. S., GRABOWSKY, G. A., BARNETT, S. H. & DESNICK, R. J., 1982. Accelerated skeletal deterioration after splenectomy in Gaucher type I disease. *American Journal of Roentgenology, 139,* 1202–1204.

SCHNEIDER, E. L., EPSTEIN, C. J., KABACK, M. M. & BRANDES, D., 1977. Severe pulmonary involvement in adult Gaucher's disease: report of three cases and review of the literature. *American Journal of Medicine, 63,* 475–480.

STRICKLAND, B., 1958. Skeletal manifestations of Gaucher's disease with some unusual findings. *British Journal of Radiology, 31,* 246–253.

Book reviews

Radiation Oncology. Vol. 2. Ed. by Theodore L. Phillips and William Wara, pp. x+173, 1986 (Raven Press, New York), $75.50.
ISBN 0-89004-957-2

This volume is the second in the series originally entitled *Radiation Oncology Annual* and is intended to be issued at 2-3 year intervals. It is a collection of seven articles, three of which detail treatment techniques, hyperthermia, stereotaxic brain implantation and photodynamic therapy. Two further chapters are devoted to the treatment of lung cancer and large bowel cancer and there are further chapters on three-dimensional planning and nuclear magnetic resonance imaging in cancer.

The chapters related to techniques are well written with good reviews of the literature and are certainly of interest. In particular, the chapter on hyperthermia is very comprehensive and presents a good review of the scientific and biological basis of hyperthermia and the experience of combining hyperthermia with radiation in the experimental setting. The section devoted to clinical results is short but contains a good series of references. The diagrams in this chapter are extremely helpful and the chapter would provide a good basis for further reading for anyone becoming interested in hyperthermia. Similarly, the chapter on photodynamic therapy is also extremely well written with a comprehensive review of both the scientific and clinical data, well presented tables and an extensive list of references. The chapter on stereotaxic implantation of gliomas with iodine 125 details the experience at the University of California, San Francisco and presents their own clinical results of therapy. Three-dimensional planning is becoming of increasing interest in radiotherapy with the prospect of conformational treatment being available with computer-controlled linear accelerators. The chapter relating to this explores the uses of three-dimensional planning in defining complicated tumour volumes, sparing normal tissues and allowing tissue correction factors to be incorporated into the dosimetry.

The chapter on nuclear magnetic resonance in cancer diagnosis seems rather out of place in that a large amount of information has been condensed into a very short chapter. As such, the criticism could be made that no one area of application of magnetic resonance imaging (MRI) is sufficiently detailed. However, the general introduction could be helpful to trainees in radiotherapy and oncology who are not familiar with the basic principles of MRI or with the advantages and disadvantages of this technique. The two chapters on clinical care of patients with large bowel cancer and lung cancer seem rather out of place in this book which is otherwise detailing new techniques. The chapter on large bowel cancer presents a case for radiation therapy as either primary or adjuvant treatment in association with surgery and gives a good review of the subject with helpful tables and references. However, the chapter on lung cancer is the weakest chapter in the book in that there is no real review of treatment techniques and regimes are presented for both the small cell carcinoma of the lung and non-small cell carcinoma, without discussion. I felt that this chapter was unnecessary.

In all, this book contains interesting chapters on hyperthermia, stereotaxic brain implantation with radioactive sources, photodynamic therapy and three-dimensional radiotherapy planning. It would be of interest to trainees in radiotherapy and oncology and would be valuable as an addition to the departmental library. The presentation of the book is pleasing and the style is readable.

P. Blake

Care of the Cancer Patient. 2nd edit. By L. G. Capra, pp. 476, 1986 (MacMillan, Basingstoke), £28.50 (hardback), £12.95 (paperback).
ISBN 0-333-38615-9 (hbk)
0-333-38616-7 (pbk)

This book, purporting to be an established nursing textbook, has been rewritten to bring up to date, not only techniques and methods of treatment, but also nursing attitudes and approaches to care. This is not a nursing textbook but a comprehensive medical one, written in a simplistic way for nurses. Its conciseness leaves the student needing more explanation and the more informed oncology nurse disappointed.

The author's philosophy is reflected in the title but it comes over as essentially "doctor-centred". Throughout the book his nursing attitudes and approaches to care are narrow and dated. Why is there no mention of the specialist roles oncology nurses adopt, or discussion on the valuable contribution to care the stoma, mastectomy and MacMillan nurses now make?

Nursing care in the text is based on the medical model and is far from comprehensive, *e.g.* on cytotoxic drugs it ends "The aim of the nursing care can be summed up as prevention." This fails to portray anything of the extent of the nurses' role. There is nothing on central venous lines and pumps and their implications in patient education. And why nothing on the essential psychological support? Pain control and fungating lesions, both difficult and challenging issues for the nurse, are covered in one paragraph!

The oncology "team" is acknowledged but surprisingly little is said of the radiographer, the physicist and the pharmacist, to name but a few important members of the team. Similarly, the chapter on the patient and family, those central in the "team", is left to near the end—hardly a multidisciplinary approach to care! The paragraph on the dietician starts "Patients rarely need this member of the team". This belies the theory and comments on page 97, "poor nutrition potentiates radiation reaction and delays healing" and "the dietician is an important member of an oncology team". Surely the support and advice of a well informed, interested dietician is needed even more today with the barrage of conflicting alternative diets?

The text is well laid out, clearly organised and easy to read with headings and subheadings. It adopts a systematic approach with basic anatomy and physiology followed by investigation and treatment options for the disease. It is fairly well illustrated with photographs and line drawings but could use more tables and back-up reference material—there are no oncology nursing textbooks or journals mentioned in "further reading".

This book may contain what the author thought nurses wanted to know but it fails to address many important aspects of care and portrays a very limited, old fashioned view of the oncology nurse's role. I would not recommend nurses to purchase this book individually but it may be a useful library reference book on medical issues.

M. M. J. MacIntyre

1987, *The British Journal of Radiology*, 60, 1197–1204 DECEMBER 1987

Computed tomographic myelography in the investigation of childhood scoliosis and spinal dysraphism

C. I. Rothwell, M.B., Ch.B., W. St C. Forbes, M.B., B.Ch., F.R.C.R. and S. C. Gupta, M.B., M.R.C.P., F.R.C.R.

Departments of Radiology, Royal Manchester Children's Hospital, Pendlebury and Hope Hospital, Eccles, Manchester

(*Received February 1987*)

ABSTRACT

The combined investigations of positive contrast myelography and computed tomographic (CT) myelography were performed on 53 consecutive children. Thirty-eight (72%) of these investigations were performed as a routine pre-operative procedure to identify occult spinal dysraphism in patients with childhood scoliosis; the remainder were because of the "orthopaedic syndrome", cervical radiculopathy, back pain and patients with clinical findings to suggest spinal dysraphism. In the 20 patients (38%) with idiopathic scoliosis, there was no case of spinal dysraphism and CT myelography provided no additional information to the myelogram. In the seven patients with spinal dysraphism the plain radiographic abnormalities identified were lumbar vertebral abnormalities (five), thoracic vertebral abnormalities (one), and sacral agenesis (one). Diastematomyelia was found in four patients, a low tethered cord and lipoma in two patients and a large lipoma in one patient. In all of these cases the myelogram indicated the intraspinal abnormalities; however, CT myelography provided more precise anatomical detail. We conclude that CT myelography is not indicated in the initial pre-operative assessment of idiopathic scoliosis but should be reserved for patients with congenital or complicated scoliosis where the association with dysraphism is well recognised.

The association of congenital scoliosis and spinal dysraphism is well recognised and the need to diagnose intraspinal anomalies prior to surgical management of the scoliosis is generally accepted (McMaster, 1984). Diastematomyelia is the commonest anomaly and the radiographic appearances are of widening of the neural canal and, almost invariably, spina bifida of some degree (Neuhauser et al, 1950). The myelographic findings include low position of the conus medullaris, a thickened filum terminale and translucencies in the contrast column (Gryspeerdt, 1963). Harwood-Nash et al (1978) and Resjo et al (1978) have described the use of computed tomographic metrizamide myelography in spinal dysraphism and concluded that it is now the investigation of choice.

The aim of this study was to assess the reasons for the combined radiological investigations of contrast myelography and computed tomographic (CT) myelography, and to evaluate the findings and the role of each procedure.

PATIENTS AND METHODS

All the children included in this study were admitted to the Royal Manchester Children's Hospital for combined myelography and CT between January 1983 and May 1986.

Fifty-three children (Table I) were examined using the combined investigation; referrals were mainly from the orthopaedic department (45 patients), the remainder being neurosurgical. Twenty were male and 33 female. Ages ranged from 1 year to 18 years; mean 11.73 years.

The orthopaedic referrals were because of pre-operative assessment of scoliosis (38 patients), the "orthopaedic syndrome" (6 patients) and dorsal back pain (1 patient).

The scoliosis patients were further divided into an idiopathic group in which there was no evidence of congenital bony anomalies (20 patients: seven male and 13 female; aged 6–18 years, mean 13.7 years); a congenital group in which the scoliosis was associated with congenital spinal anomalies such as hemivertebrae or spina bifida (13 patients: seven males and six females, aged 2.5–16 years, mean 12.2 years) and a miscellaneous group of five patients.

TABLE I

CLINICAL PROBLEMS IN 53 PATIENTS

	No. of patients
Idiopathic scoliosis	20
Congenital scoliosis	13
Neuromuscular disorder and scoliosis	1
Cerebral palsy and scoliosis	1
Spastic hemiparesis and scoliosis	2*
Spinal dysraphism without scoliosis	5
Osteochondrodystrophy	1†
"Orthopaedic syndrome"	6
Cervical radiculopathy	3‡
Dorsal back pain	1
Total	53

The neurosurgical referrals included five patients in which spinal dysraphism was clinically suspected (four female and one male, aged 1–11 years, mean 4.8 years) and three patients with a cervical radiculopathy (two female and 1 male, aged 6–15 years, mean 9.3 years).

The majority of the examinations were performed via a lumbar puncture (45 investigations). However, when this was not feasible, the cisternal route (seven investigations) or a lateral C1/C2 puncture (one investigation) was used.

The intrathecal injection was given using local anaesthesia unless precluded by the patient's age or inability to co-operate, or use of the cisternal route, in which cases general anaesthesia was required.

The myelographic technique depended upon the radiologist performing the examination but usually involved supine, lateral, prone and oblique views of the lumbar region and prone and lateral views of the thoracic spine.

All except one of the CT myelography examinations were performed on the EMI 5005 scanner. Sections were taken at 1 cm or 2 cm intervals, depending upon the initial findings from the myelogram. One patient was scanned on the Philips 305N CT scanner.

Initially the intrathecal agent used was metrizamide (Amipaque, Nyegaard) either 200 mg/ml or 230 mg/ml (14 investigations). Later, as the newer, non-ionic contrast agents became available, iohexol 240 mg/ml (35 investigations), iohexol 300 mg/ml (two investigations) and iopamidol 300 mg/ml (two investigations), were used. The volume of contrast medium used depended upon the age and weight of the patient but was between 6 ml and 15 ml.

The following features were assessed from the combined examinations:

(i) low position of the conus medullaris (below L2),
(ii) a dorsally located filum terminale,
(iii) width of filum terminale greater than 2 mm,
(iv) the presence of translucencies in the contrast column to indicate intrathecal tumours or traction bands.

RESULTS

All 20 patients with idiopathic scoliosis were being investigated prior to surgical corrections or fusion of the spinal deformity. In none of these patients were there any neurological findings. In each case the myelographic findings were normal and, in particular the conus medullaris was never identified below the L2 level. The CT myelography provided no significant additional findings and there was no evidence of spinal dysraphism.

Four patients from the congenital scoliosis group (Table II) were found to have spinal dysraphism. Two patients (Cases 27, 28) had abnormally low spinal cords and terminal lipomas (Fig. 1); another (Case 30) had a thoracic diastematomyelia (Fig. 2) and another (Case 31) had a tethered filum terminale and a large lipoma (Fig. 3). These patients all had abnormal vertebral morphology on plain radiograph and abnormal myelograms indicating the lesion; CT myelography proved confirmatory.

Case 35 (Table I*) involved an 18-year-old girl who developed a thoracic kyphoscoliosis secondary to a spastic quadriplegia following a road traffic accident. Computed tomographic myelography demonstrated a small terminal lipoma which was missed on the initial myelogram but was clearly identified on review. This was regarded as of no surgical significance and a straightforward spinal fixation was performed.

Case 38 (Table I†) involved a 3-year-old boy with severe thoracic scoliosis associated with osteochondrodystrophy. The myelogram was inconclusive but an intradural lesion was suspected. Findings from CT myelography were suboptimal due to motion artefact but an intrathecal lipoma was identifed. An exploratory

TABLE II

RADIOLOGICAL FINDINGS IN 13 PATIENTS WITH CONGENITAL SCOLIOSIS

Case	Sex	Age (years)	Plain-radiographic findings	Myelogram/CT myelogram
21	M	14	Thoracic hemivertebrae	Normal
22	M	2.5	Thoracic hemivertebrae	Normal
23	F	11	Flattened lumbar vertebrae	Normal
24	F	12	Thoracic hemivertebrae	Normal
25	F	11	Thoracic hemivertebrae	Normal
26	F	15	Thoracic hemivertebrae	Normal
27	F	13	Lumbar spina bifida	Tethering/lipoma
28	M	13	Lumbar spina bifida	Tethering/lipoma
29	M	9	Lumbar spina bifida	Normal
30	M	13	Lumbar spina bifida	Thoracic diastematomyelia
31	M	15	Thoracic spina bifida	Large lipoma
32	F	16	Lumbar spina bifida	Normal
33	M	14	Thoracic hemivertebrae	Normal

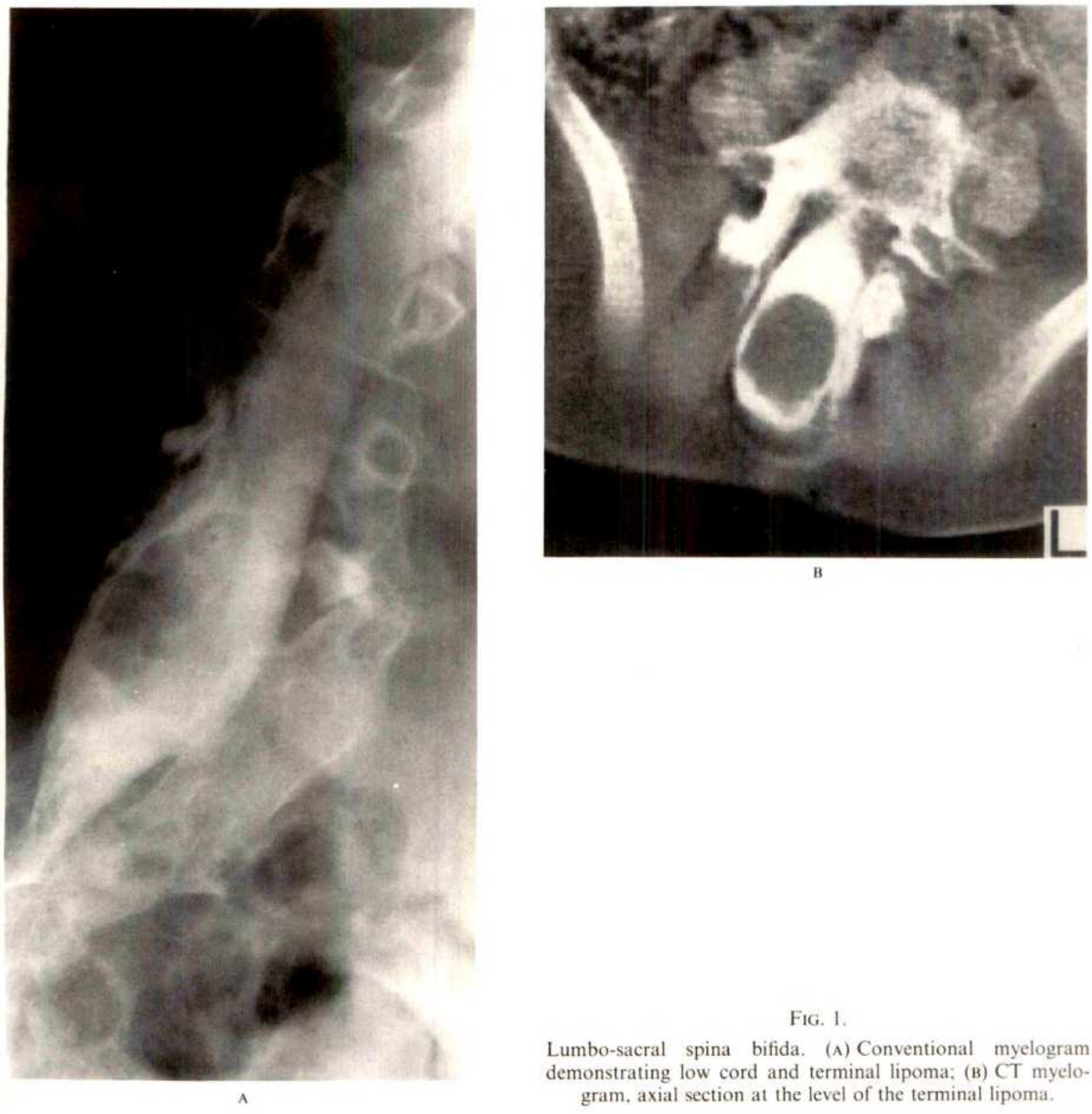


FIG. 1.

Lumbo-sacral spina bifida. (A) Conventional myelogram demonstrating low cord and terminal lipoma; (B) CT myelogram, axial section at the level of the terminal lipoma.

laminectomy from T7 to L1 failed to find a lesion. This false positive was thought to be the result of an interpretative error due to the dystrophic vertebrae.

The six patients with the "orthopaedic syndrome" showed no evidence of spinal dysraphism. The plain radiographs, myelograms and CT myelography revealed no significant abnormality.

Five of the neurosurgical referrals (Table III) had clinical evidence to suggest spinal dysraphism. Neurological examinations of one patient (Case 49) revealed a wasted right leg, absent knee reflexes and a neurogenic bladder. Plain radiographs showed sacral agenesis and a dysraphic spine from L2 to L5. Myelography indicated sacral diastematomyelia which was confirmed by CT myelography. The patient in Case 50 had a sacrococcygeal sinus but no neurological abnormality. The myelogram showed no evidence of diastematomyelia. The conus appeared to be at L3 but CT myelography demonstrated the conus to be at the normal level of L1/L2. Another patient (Case 51) had lumbar spina bifida but no neurological deficit. Myelography demonstrated a wide spinal canal and a linear filling defect indicating diastematomyelia. Computed tomographic myelography confirmed a lower thoracic diastemato-

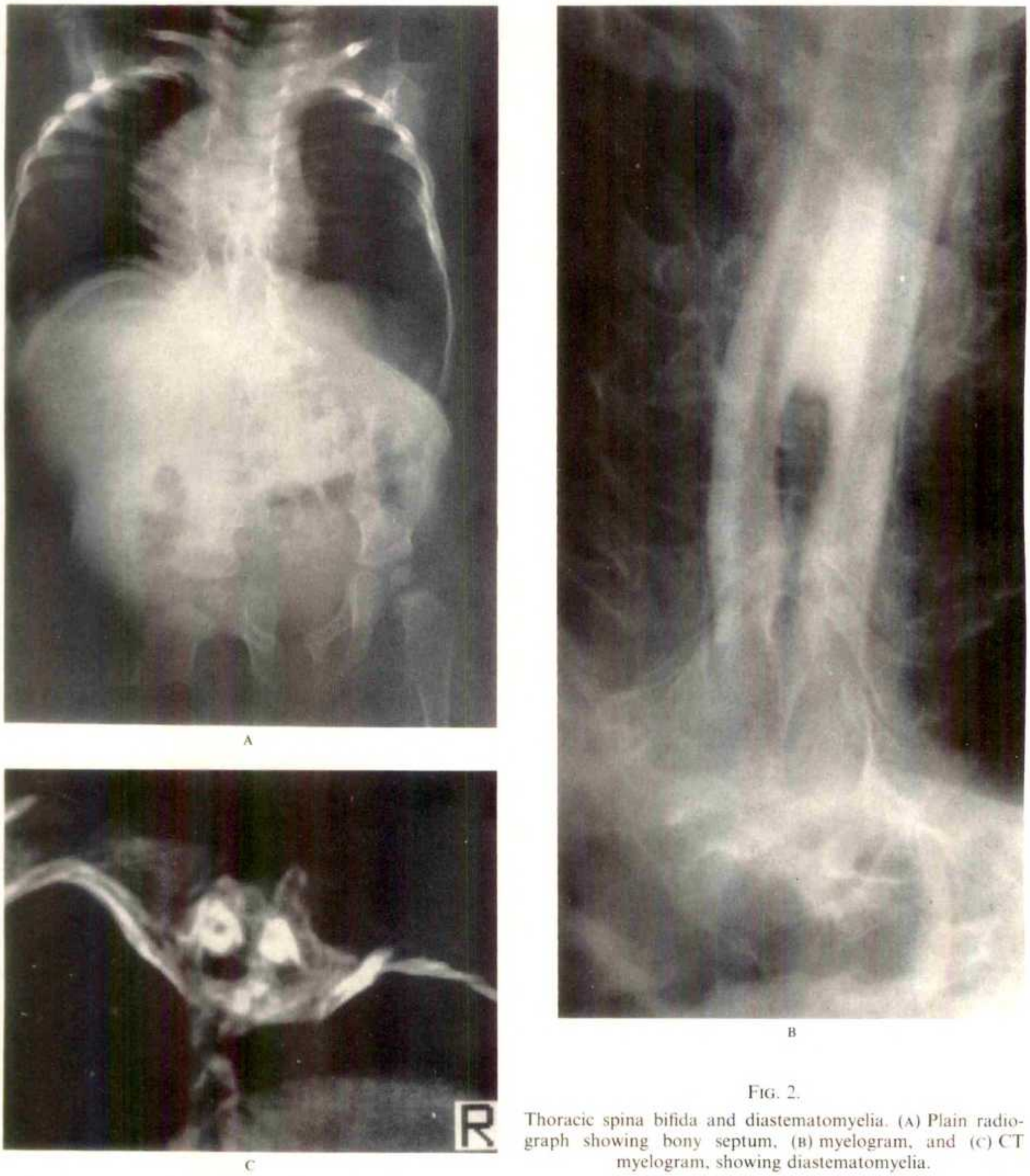
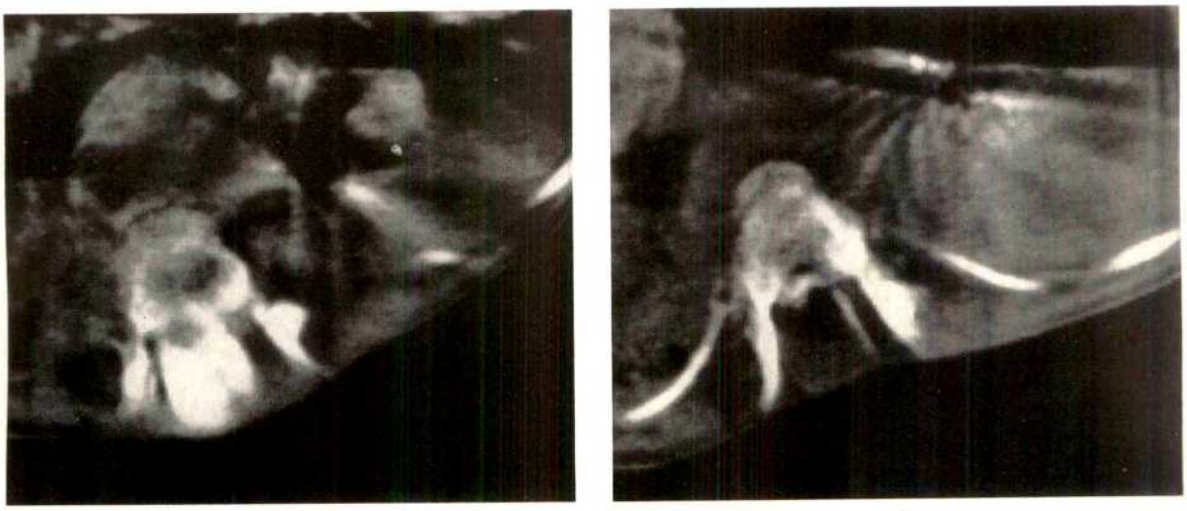


FIG. 2.

Thoracic spina bifida and diastematomyelia. (A) Plain radiograph showing bony septum, (B) myelogram, and (C) CT myelogram, showing diastematomyelia.

myelia but no evidence of a bony septum. The patient in Case 52 had lumbar spina bifida with increased tone in both legs. Both the myelogram and the CT myelogram were normal. One patient (Case 53) had had previous repair of a lumbar myelo-meningocoele and a possible leak of cerebrospinal fluid. Myelography indicated a low cord at L3 (Fig. 4A) being tethered posteriorly; the thoracic region was not examined. The CT myelography confirmed these findings and, in addition, demonstrated a thoracic diastematomyelia (Fig. 4B).

The remaining three neurosurgical referrals were for



A B

FIG. 3.

Thoracic spina bifida, transaxial CT myelogram. (A) posterior tethering of filum; (B) contiguous section showing lipoma.

the investigation of cervical radiculopathy and therefore only cervical examinations were performed. The myelogram in Case 48 (Table I‡) indicated possible expansion of the cord; however, CT myelography proved normal.

DISCUSSION

Spinal dysraphism is a term used to cover developmental anomalies arising in the dorsal median region in the embryo. Lichtenstein (1940) stated that dysraphism was "primarily an expression of inadequate or improper fusion of the embryonic tissues in the dorsal median region of the developing embryo; the resultant pathological states will be manifested in the cutaneous, mesodermal or neural derivatives of these tissues". The best known clinical form is meningomyelocoele which is an example of an overt lesion involving cutaneous, mesodermal and neural elements. Occult spinal dysraphism includes such abnormalities as diastematomyelia, congenital intra- and paraspinal masses such as neurenteric cysts, dermoid cysts, teratomas, and lipomas, and low spinal-cord conus.

McMaster (1984), in a series of 251 patients with congenital scoliosis found occult congenital intraspinal anomalies in 46 patients (18.3%). Diastematomyelia was the commonest anomaly (41 patients). Clinically, the intraspinal anomalies presented in several ways. Fifteen (33%) of the 46 patients were seen not because of the scoliosis, but because of either a cutaneous abnormality on the back or a neural deficit in the lower limbs or bladder.

James and Lassman (1960) described the association of occult spinal dysraphism and limb inequality and referred to this as the "orthopaedic syndrome". It is characteristically insidious, with slow progression, with or without midline cutaneous anomalies. Muscle wasting, asymmetry and weakness of the lower extremities, peculiar gait and late reflex changes are often present. Bladder and bowel involvement may occur and at times bladder dysfunction may be the only

TABLE III

RADIOLOGICAL FINDINGS IN FIVE PATIENTS WITH CLINICALLY SUSPECTED SPINAL DYSRAPHISM

Case	Sex	Age (years)	Neurological findings	Plain-radiographic findings	Myelogram/ CT myelogram
49	F	5	Neurogenic bladder/wasted right leg	Sacral agenesis; dysraphism L2–L5	Sacral diastematomyelia
50	F	2	No	Sacral spina bifida	Normal
51	F	1	No	Lumbar spina bifida	Diastematomyelia
52	F	11	Increased tone in legs	Lumbar spina bifida	Normal
53	M	5	Paraplegia	Lumbar spina bifida	Tethered cord; thoracic diastematomyelia

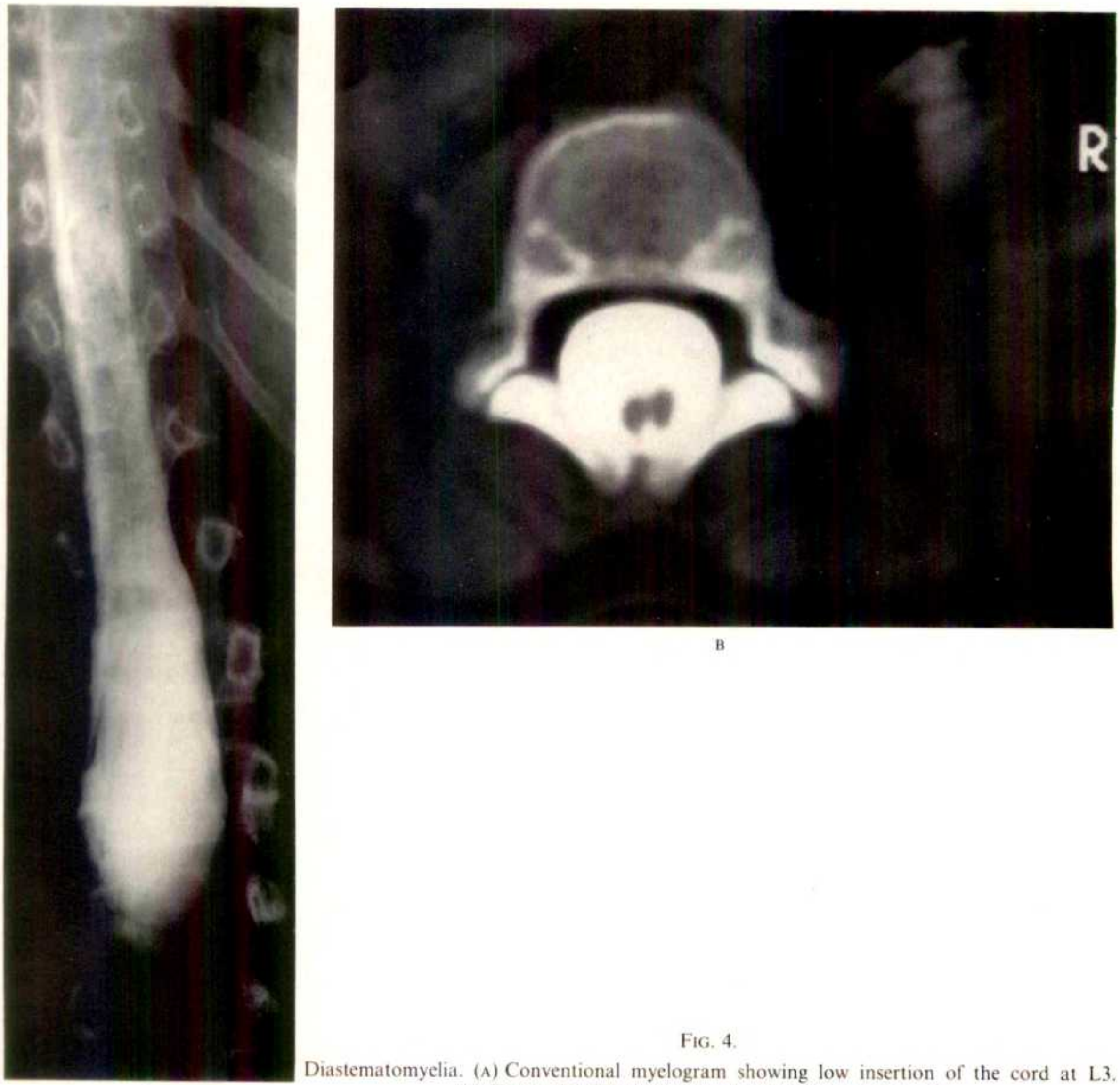


FIG. 4.
Diastematomyelia. (A) Conventional myelogram showing low insertion of the cord at L3. (B) Transaxial CT myelogram showing diastematomyelia.

salient feature (Thomas & Miller, 1973). The syndrome of the tethered cord has also been implicated in this entity (James & Schut, 1974; Fitz & Harwood-Nash, 1975).

It has been suggested that the neural abnormalities that occur in association with diastematomyelia, and other congenital intraspinal anomalies are due to traction on the spinal cord. In early embryonic life, the spinal cord occupies the entire length of the vertebral canal, but due to differing rates of growth and differentiation of the neural tube compared with the osseous elements there is an apparent cranial migration of the conus medullaris until it reaches its final level at the upper border of the second lumbar vertebra. During this process, any tethering of the cord by an intraspinal anomaly could result in a neural deficit. Barson (1970) has shown that the ascent of the spinal cord is most rapid during the first half of intrauterine life, and that the final level is reached 9 weeks after birth. Thus, neural abnormalities due to simple axial tethering of the cord should be present at birth and further deterioration should be minimal. Secondly, if this hypothesis were correct, one would expect axial traction of the spinal cord to produce bilateral neural deficits whereas in the majority of patients the symptoms and signs are unilateral.

Guthkelch (1974) has suggested an alternative and more acceptable theory, that the unilateral syndrome affecting the lower limbs of these children may be due to a unilateral developmental anomaly of the cord on one side of the diastematomyelia. The resulting neural abnormality is present at birth but it is only as the child begins to walk that the limp or limb asymmetry becomes evident. This abnormality was demonstrated by Lichtenstein (1940) pathologically in three separate patients and he used the term myelodysplasia to describe the maldevelopment of the spinal cord and its ganglia. Similarly, Shaw (1975) suggested "myelodysplastic syndrome" as a suitable description of the characteristic abnormalities in the lower limbs of these children.

Guthkelch (1974) further stated that the orthopaedic syndrome is an unalterable, prenatally determined condition due to a primary disturbance of neural–mesodermal interaction, whereas the cause of progressive spinal cord damage is repeated minor trauma from the fibrous or bony band during spinal flexion. Further, the risk of damage continues throughout childhood, so that the removal of the spur should be considered at whatever age it is discovered.

McMaster (1984) suggested that, once diagnosed, an intraspinal anomaly should be treated as a prophylactic measure in all children less than 6 years old who have congenital scoliosis, regardless of their neural status. The intraspinal anomaly should also be treated immediately in patients who are more than 6 years old if the congenital scoliosis is thought likely to require correction and fusion at a later stage. The hypothesis that spinal traction, corrective casts or intraoperative instrumentation may stretch the spinal cord and cause neurological deficit in a patient with scoliosis and occult diastematomyelia is validated by a case reported by Sharey (1955), of a 12-year-old boy in whom spontaneous paraparesis developed during cast treatment of kyphoscoliosis.

Keim and Kreen (1973) reviewed 20 patients with diastematomyelia, 14 of whom had an associated scoliosis. They showed that the curvature of the scoliosis was dependent on bony anomalies of the vertebrae accompanying the diastematomyelia and not on neurological deficits. Because of the danger of cord damage, the bony spike or fibrous band should be removed prior to surgery for the scoliosis. They concluded that before surgery any patient with scoliosis and with congenital anomalies of the spine should have myelography.

The radiological finding in diastematomyelia of fusiform widening of the neural canal is characteristic of the condition, in addition to which, spina bifida of some degree is almost invariable. Other spinal anomalies seen are hemivertebra defects or failures of segmentation (congenital bars or block vertebrae) (Neuhauser et al, 1950; Winter et al, 1974).

The myelographic findings in spinal dysraphism have been well described by Gryspeerdt (1963) and include a low position of the conus medullaris, a dorsally located filum terminale, width of filum terminale greater than 2 mm and translucencies in the contrast-medium column indicating tractions bands from the dura to the cord.

Harwood-Nash et al (1978) have studied the appearances of spinal dysraphism with CT myelography using metrizamide and concluded that it was the investigation of choice in providing details of the often complex pathological anatomy of the dysraphic spine.

The results of this study certainly confirm the finding of Harwood-Nash et al (1978), that anatomic detail of the dysraphic state is best provided by CT myelography. However, we have also confirmed that the standard myelographic examination remains an accurate method of visualising, or at least indicating, the possibility of spinal dysraphism. The association of spinal dysraphism and congenital scoliosis is well proven but no association with idiopathic scoliosis has been shown. In this study, 20 patients with idiopathic scoliosis received the additional radiation dose associated with a CT myelography examination and yet no additional information was obtained. The orthopaedic management of idiopathic scoliosis involves several radiographic examinations of the spine to assess the progression of the deformity, usually in adolescence and mostly without gonadal protection. This study would suggest that the further radiation dose from a CT examination is not necessary as a standard screening investigation. Therefore, in a patient with idiopathic scoliosis in which there is no clinical evidence of dysraphism such as abnormal vertebral morphology, a cutaneous skin lesion or neurological deficit, a standard myelographic examination should be sufficient to exclude occult spinal dysraphism. Thus, CT myelography should be reserved for the investigation of congenital and complicated scoliosis.

ACKNOWLEDGMENTS

We should like to thank our orthopaedic and neurosurgical colleagues who referred the patients and Mrs B. Bates for secretarial support.

REFERENCES

BARSON, A. J., 1970. The vertebral level of termination of the spinal cord during normal and abnormal development. *Journal of Anatomy*, *106*, 489–497.

FITZ, C. R. & HARWOOD-NASH, D. C. F., 1975. The tethered conus. *American Journal of Roentgenology*, *125*, 515–523.

GRYSPEERDT, G. L., 1963. Myelographic assessment of occult forms of spinal dysraphism. *Acta Radiologica Diagnosis*, *1*, 702–717.

GUTHKELCH, A. N., 1974. Diastematomyelia with median septum. *Brain*, *97*, 729–742.

HARWOOD-NASH, D. C. F., FITZ, C. R., RESJO, M. & CHUNG, S., 1978. Congenital spinal and cord lesions in children and computed tomographic metrizamide myelography. *Neuroradiology*, *16*, 69–70.

James, C. C. M. & Lassman, L. P., 1960. Spinal dysraphism. An orthopaedic syndrome in children accompanying occult forms. *Archives of Disease in Childhood, 35*, 315–327.

James, H. E. & Schut, L., 1974. The spontaneous remission of a large sacrococcygeal lipomeningococoele sac with presentation of a tethered cord syndrome. *Neuropaediatrics, 5*, 340–343.

Keim, H. A. & Kreen, A. F., 1973. Diastematomyelia and scoliosis. *Journal of Bone and Joint Surgery, 55A*, 1425–1435.

Lichtenstein, B. W., 1940. Spinal dysraphism. Spina bifida and myelodysplasia. *Archives of Neurology and Psychiatry, 44*, 792–810.

McMaster, M. J., 1984. Occult intraspinal anomalies and congenital scoliosis. *Journal of Bone and Joint Surgery, 66A*, 588–601.

Neuhauser, E. B. D., Wittenburg, M. H. & Dehlinger, K., 1950. Diastematomyelia: transfixation of the cord or cauda equina with congenital anomalies of the spine. *Radiology, 54*, 659–664.

Resjo, M., Harwood-Nash, D. C. F., Fitz, C. R. & Chuang, S., 1978. Computed tomographic metrizamide myelography in spinal dysraphism in infants and children. *Journal of Computer Assisted Tomography, 2*, 549–558.

Sharey, W. D., 1955. Diastematomyelia associated with dorsal kyphosis producing paraplegia. *Journal of Neurosurgery, 12*, 300–305.

Shaw, J. F., 1975. Diastematomyelia. *Developmental Medicine and Child Neurology, 17*, 361–364.

Thomas, J. E. & Miller, R. H., 1973. Lipomatous tumours of the spinal cord. *Mayo Clinic Proceedings, 48*, 393–400.

Winter, R. B., Haven, J., Moe, J. H. & Lagaard, S. M., 1974. Diastematomyelia and congenital spine deformities. *Journal of Bone and Joint Surgery, 56A*, 27–39.

1987, *The British Journal of Radiology*, *60*, 1205–1209 DECEMBER 1987

Quantitative assessment of lung damage due to bleomycin using computed tomography

By *Elizabeth A. Bellamy, M.R.C.P., F.R.C.R., †David Nicholas, B.Sc., Ph.D. and Janet E. Husband, F.R.C.P., F.R.C.R.

Royal Marsden Hospital and Institute of Cancer Research, Sutton, Surrey SM2 5PT

(*Received January 1987 and in revised form April 1987*)

ABSTRACT

Visual assessment and density measurements of the lung using computed tomography (CT) were made in 18 patients undergoing treatment with bleomycin for malignant teratoma of the testis. The results of both visual assessment and density measurements were compared with changes in gas transfer per unit lung volume (KCO). Visual assessment of severity of damage to the lungs caused by bleomycin is unrelated to changes in KCO but is characteristic of bleomycin damage and allows a confident diagnosis to be made. Quantitative density measurement by CT, however, is inversely related to changes in KCO and may therefore be used to monitor the physiological effect on the patient. Examination of the lung by CT in these patients can not only characterise and define the extent of lung damage due to bleomycin but can be used to give a quantitative measurement on which to monitor treatment.

Bleomycin is commonly used in the treatment of patients with lymphoma and seminomatous and non-seminomatous germ-cell tumours of the testis. As these conditions now carry a favourable prognosis in the majority of patients, it is essential that the treatment does not result in long-term disability. Bleomycin, however, is associated with the development of pulmonary toxicity, the severity relating to dose, patient age and previous radiotherapy (Blum et al, 1973; Einhorn et al, 1976), although such damage may be reversible if detected at an early stage (Brown et al, 1978). At present, the most reliable method for detecting early damage involves lung function studies, particularly measurement of changes in carbon monoxide diffusion capacity. However, this is non-specific (Cotes, 1979) and gives no indication of the extent of the disease. In contrast, examination by computed tomography (CT) shows an appearance characteristic of bleomycin change and can demonstrate the extent of lung damage but visual assessment of the grade of damage does not appear to relate to changes in carbon monoxide diffusion capacity (Bellamy et al, 1985; Rimmer et al, 1985). This obviously limits its usefulness in early detection. Using CT, the information obtained by visual assessment is hindered by the large density differences within the lung. However, the digital nature of conventional systems enables one to quantify density to a precision which enables small changes to be detected which are not apparent visually.

The purpose of this study was (i) to define a model on which to base our quantitative analysis of bleomycin damage; (ii) to determine whether a quantitative measurement of density change could be achieved between pre- and post-treatment scans; and (iii) to compare pre- and post-treatment lung density with results of lung function tests, namely total lung capacity (TLC) and gas transfer per unit lung volume (KCO).

METHOD

Eighteen patients (age range 22–47 years) were incorporated in this study; all were being treated for malignant teratoma of the testis and had undergone pre-treatment CT scans through the chest and abdomen as an initial staging procedure. All patients then received bleomycin as part of their combination chemotherapy, the other drugs used being cisplatinum, vinblastine and ectoposide. Courses of chemotherapy were given at 21-day intervals where bleomycin (30 mg) was administered on Days 2, 9 and 16 of each course. All patients received four courses, the total dose of bleomycin being 360 mg.

Following chemotherapy, patients underwent follow-up CT assessment of the chest and abdomen. Scans were obtained on a Somatom 2 body scanner, scan time 10 s, using contiguous 8 mm slices. Scans through the chest were made during suspended mid-inspiration. Lung function tests (TLC, KCO) were performed 4 weeks after the last dose of bleomycin. Although some patients had pre-treatment assessment of lung function, several had unavoidably undergone lymphography before the measurement, thereby invalidating such results (Gold et al, 1965).

Total lung capacity was measured by whole-body plethysmography, and KCO with a Morgan respirometer. Results for KCO were corrected for the haemoglobin level, and all test results were expressed as a percentage of predicted values for each individual based on age and height (Cotes, 1979).

The 18 patients included in the study had normal pre-treatment CT scans of the chest. Follow-up CT examination was performed within 5 days of the lung function studies, when all 18 patients demonstrated visual evidence of bleomycin damage. Based on previous studies which showed that the earliest visual change occurred peripherally (Bellamy et al, 1985; Rimmer et al, 1985), we accordingly chose this region for analysis of the density change.

---

*Consultant Radiologist, Ashford and West Middlesex University Hospitals.

†Head, Radiotherapy Physics, Norfolk and Norwich Hospital.

For the purpose of our study an upper limit of −100 HU was set to define the outer boundary of the lung. This density was chosen such that all but the most severe damage would be included within the outline and yet the value was sufficiently low to enable complete separation of lung from mediastinum and chest wall and hence outline the lungs. A computer program was written which automatically searched for this level and superimposed the required outline on the image (Fig. 1). Since the density changes to be quantified relate to the periphery of the lung, it is unnecessary to quantify the whole lung cross-section and, indeed, undesirable since the vascular structures dominate the more central regions and thereby yield high density values which obscure subtle changes related to damage. An inner boundary was defined, by computer, 10 pixels (Fig. 2) within the outer boundary and quantification limited to this peripheral rim.

Initially, the mean and standard deviation of lung density were determined within this rim. Then the rim was sectioned into equal areas (2.9 cm^2) and the mean density of each local area calculated, with the exception of the medial regions as these are dominated by vascular structures (Fig. 2). This latter procedure was deemed necessary since small changes within a localised region would not be noticeable when only the whole rim is being monitored. It was decided that any local area which exhibited a mean density greater than the mean density of the periphery by at least one standard deviation would relate to local change due to damage, rather than normal anatomical variation. This was confirmed in the pre-treatment lung assessments, as no region of normal lung anatomy met this criterion. Finally, each lung slice was assigned a "density" index in Hounsfield units according to the following equation:

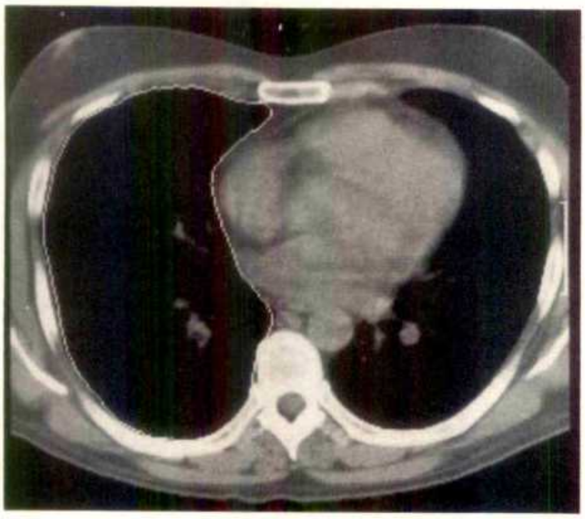


FIG. 1.

Computed tomographic section through the thorax illustrating the lung outlines generated by the computer.

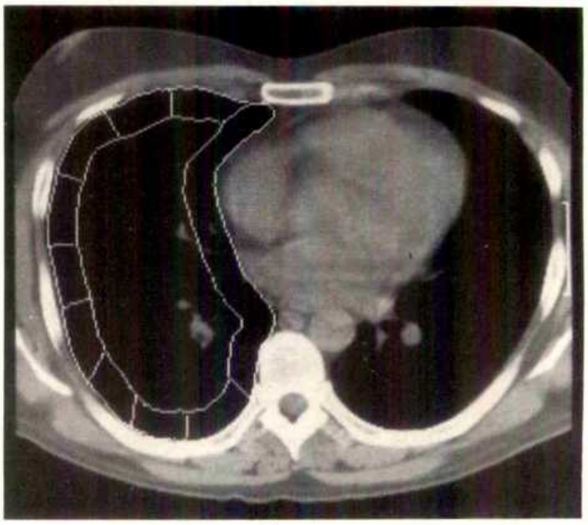


FIG. 2.

Computed tomogram depicting the peripheral region of lung selected for density analysis. The inner boundary is separated from the outer by 10 pixels (12 mm).

$$\text{"density" index (HU)} = \frac{\text{mean peripheral density} + \text{abnormal section density}}{\text{total number of sections}}$$

This procedure was performed on six selected slices from the post-treatment series of scans and on the corresponding slices from the pre-treatment series of scans, and any change in the density index that occurred was recorded.

Visual assessment of the grade of severity by CT was also noted for each patient. The grading was as follows. Minor change, involving only the outer third of the lung volume; moderate change, involving the outer and middle third of the lung volume; and severe change, involving the whole width of the lung from the periphery to the mediastinum.

Results of both the visual assessment and quantitative analysis of density change between pre- and post-treatment scans were compared with results of lung function studies TLC and KCO.

RESULTS

Visual assessment of the 18 patients indicated that 11 showed minor changes, five moderate changes and two severe changes due to bleomycin damage. Comparison of the visual assessment of severity of damage by CT with results of KCO is demonstrated in Fig. 3, confirming the finding in our previous study that there is little correlation between these two assessments.

Figure 4 demonstrates a comparison between "density" index change and changes in KCO. In contrast to the visual assessment by CT, measurements of "density" index change are seen to be inversely related to reduction in KCO. "Density" index change, however, did not relate to changes in TLC (Fig. 5).

DISCUSSION

This study has shown that there is a direct relationship between changes in lung density (HU) and measurement of gas transfer per unit lung volume. The decision to quantify density changes around the periphery of the lung was based on two previous observations. Firstly, the results of our initial study demonstrated that the earliest visual change is observed around the lung periphery (Bellamy et al, 1985) and, secondly, previous work has shown that measurements of density changes in the peripheral part of the lung reflect changes in the lung parenchyma more reliably as there are fewer vascular opacities here than nearer the centre (Rosenblum et al, 1980). The ability to quantify minimal density changes accurately makes CT unique among the other imaging modalities. Although there have been many visual assessments of the lung with CT, work regarding actual quantification of density change has received little attention, mainly because of its presumed limited clinical application (Goddard et al, 1982; Gilman et al, 1983; Van Dyk & Hill, 1983). Gilman et al (1983), in a review of 12 patients with radiographic evidence of sarcoidosis, compared results of mean lung density (MLD) measured by CT with pulmonary function tests, namely total lung capacity and single-breath diffusion capacity (DLCOsb). Their results demonstrated that, while there was correlation between changes in MLD and lung volume measurement (TLC), no direct relationship was observed between measurement of MLD and single-breath diffusing capacity. These results agree with our previous study, which compared only visual assessment of severity of lung damage with CT and results of lung function tests (Bellamy et al, 1985), but differ significantly from our latest results, which have shown a

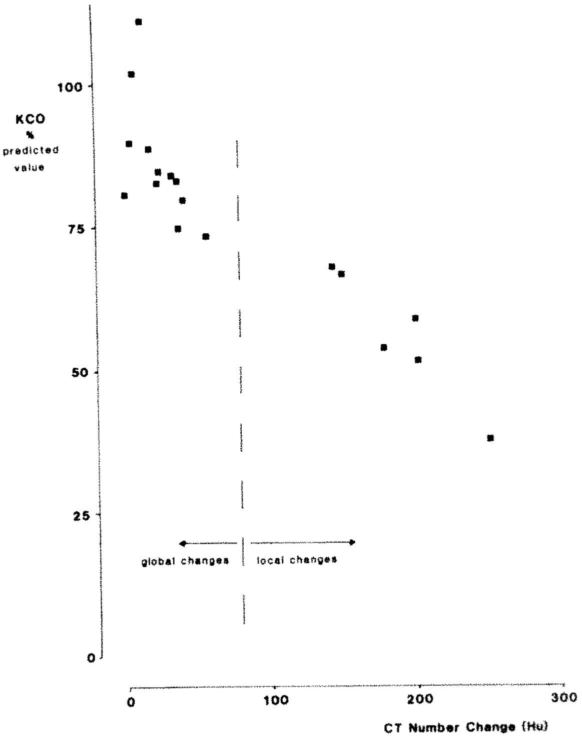


FIG. 4.

Comparison of "density" index change with KCO, expressed as a percentage of predicted value.

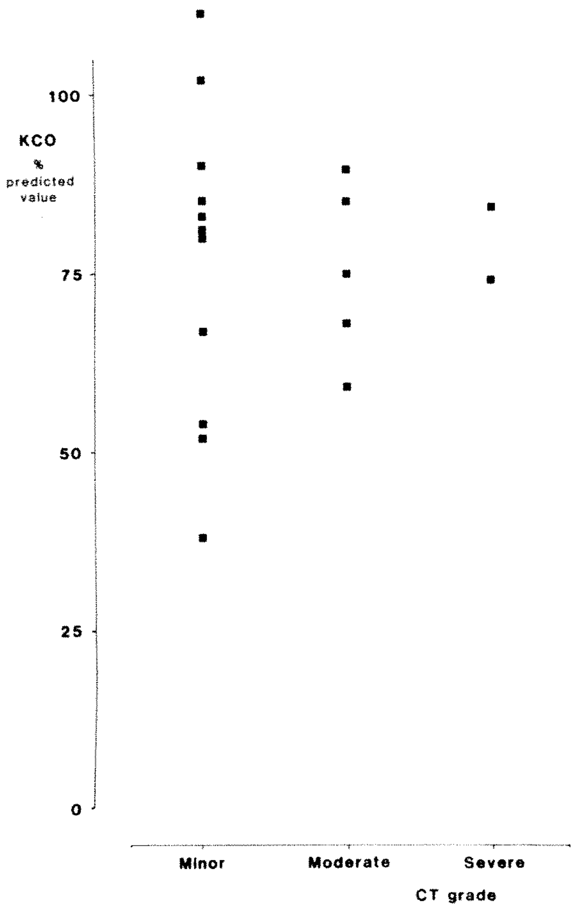


FIG. 3.

Comparison of visual assessment of severity of damage by CT with KCO, expressed as a percentage of predicted value.

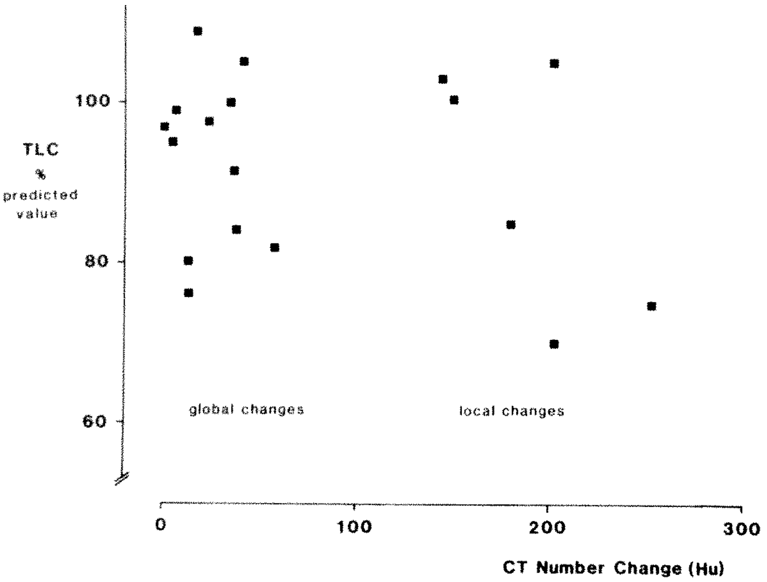


FIG. 5.

Comparison of "density" index change with TLC, expressed as a percentage of predicted value.

direct relationship with changes in peripheral lung density and measurement of gas transfer per unit lung volume. A possible explanation for this finding may be the method employed in our analysis of mean lung density measurement. Gilman et al (1983) analysed the mean lung density within a pre-selected peripheral area using the method described by Rosenblum et al (1980). In contrast, our analysis was designed to take into account areas of focal increase in density which were significantly different from the surrounding average lung density around the periphery. Use of this method means that focal as well as diffuse changes in density can be noted. With ordinary analysis the significance of focal areas of increased density would have been minimised and their effect on KCO lost.

This study has important implications for the additional use of CT in patients undergoing treatment with bleomycin. Not only can information regarding the primary disease state be obtained but, by following lung density changes, the effects of bleomycin on the lung can be monitored. Although sensitive, the main problem with measurement of KCO is that it is non-specific and gives no indication of the severity of the damage present in the lung. Quantifying lung density by CT appears to give the same information as measurement of KCO but has the advantage of allowing visual assessment of the lung at the same time. This means that not only can the nature of the abnormality be seen as well as its extent, but also measurement of changes in lung density can be used to assess the physiological effect of that change.

Histologically, the effects of bleomycin on the lung have been shown to start initially with swelling of the capillary endothelial cells, oedema of the interstitium, necrosis of Type I pneumocytes and proliferation of Type II pneumocytes (Adamson, 1976; Adamson & Bowden, 1977). These changes are unlikely to cause visually obvious changes but will result in an increase in lung density and a reduction in KCO. As the damage progresses, areas of fibrosis being to appear in the septa and alveolar spaces, thus reducing the surface area available for gas transfer even further. Changes in carbon monoxide diffusing capacity can be misleading, however, even allowing for correction of haemoglobin levels (Lewis & Izbicki, 1980) and its measurement does not appear to predict serious, clinically apparent pulmonary changes (Krakoff et al, 1977). Measurement of lung volume may also be misleading due to weakness, pain or analgesia. In contrast, quantification of density change with CT is unaffected by these factors.

In summary, CT examination of the lungs in patients being treated with bleomycin can not only give characteristic appearances due to bleomycin damage but can give quantitative information regarding the physiological effect of this damage on the patient. Examination by CT may therefore provide an alternative method in the assessment of lung function and may be performed following routine assessment of the chest.

ACKNOWLEDGMENTS

The CRC Radiology Research Group at the Royal Marsden Hospital is funded by the Cancer Research Campaign, which also supported one of us (E.A.B.), and by the Department of Health and Social Security. We would like to thank Mrs Janice O'Donnell for her help in the preparation of this manuscript.

We would like to acknowledge the Lung Function Unit at the Brompton Hospital who kindly carried out the lung function tests. We are most grateful to Professor M. J. Peckham for allowing us to study patients under his care.

REFERENCES

ADAMSON, I. Y., 1976. Pulmonary toxicity of bleomycin *Environmental Health Perspectives, 16*, 119–125.

ADAMSON, I. Y. & BOWDEN, D. H., 1977. Origin of ciliated alveolar epithelial cells in bleomycin-induced lung injury. *American Journal of Pathology, 87*, 569–580.

BELLAMY, E. A., HUSBAND, J. E., BLAQUIERE, R. M. & LAW, M. R., 1985. Bleomycin-related lung damage: CT evidence. *Radiology, 156*, 155–158.

BLUM, R. H., CARTER, S. K. & AGRE, K., 1973. A clinical review of bleomycin, a new antineoplastic agent. *Cancer, 31*, 903–914.

BROWN, W. G., HASAN, F. M. & BARBEE, R. A., 1978. Reversibility of severe bleomycin induced pulmonary pneumonitis. *Journal of the American Medical Association, 239*, 2012–2014.

COTES, J. E., 1979. *Lung Function: Assessment and Application in Medicine*, 4th edit. (Blackwell Scientific, Boston), pp. 245–246, 365–387.

EINHORN, L., KRAUSE, M., HORNBACK, N. & FURNAS, B., 1976. Enhanced pulmonary toxicity with bleomycin and radiotherapy in oat cell lung cancer. *Cancer, 37*, 2414–2416.

GILMAN, M. J., LAURENS, R. G., SOMOGYI, J. W. & HONIG, E. G., 1983. CT attenuation values of lung density in sarcoidosis. *Journal of Computer Assisted Tomography, 7*, 407–410.

GODDARD, P. R., NICHOLSON, E. M., LASZLO, G. & WATT, I., 1982. Computed tomography in pulmonary emphysema. *Clinical Radiology, 33*, 379–387.

GOLD, W. M., YOUKER, J., ANDERSON, S. & NADEL, J. A., 1965. Pulmonary function abnormalities after lymphography. *New England Journal of Medicine, 273*, 519–524.

KRAKOFF, I. H., CUITKOVIC, E., CURRIE, V., YEH, S. & LA MONTE, C., 1977. Clinical pharmacologic and therapeutic studies of bleomycin given by continuous infusion. *Cancer, 40*, 2027–2037.

LEWIS, B. M. & IZBICKI, R., 1980. Routine pulmonary function tests during bleomycin therapy. Tests may be ineffective and potentially misleading. *Journal of the American Medical Association, 243*, 347–351.

RIMMER, M. J., DIXON, A. K., FLOWER, C. D. R. & SIKORA, K., 1985. Bleomycin lung: computed tomographic observations. *British Journal of Radiology, 58*, 1041–1045.

ROSENBLUM, L. J., MAUCERI, R. A., WELLENSTEIN, D. E., THOMAS, F. D., BASSANO, D. A., RAASCH, B. N., CHAMBERLAIN, C. C. & HEITZMAN, E. R., 1980. Density patterns in the normal lung as determined by computed tomography. *Radiology, 137*, 409–416.

VAN DYK, J. & HILL, R. P., 1983. Post irradiation lung density changes as measured by computerised tomography. *International Journal of Radiation Oncology, Biology, Physics, 9*, 847–852.

Book reviews

Computed Tomography of the Gastrointestinal Tract. Ed. by A. J. Megibow and E. J. Balthazar, pp. xi + 463, 1986 (C. V. Mosby, St Louis), £55.50.
ISBN 0-8016-3376-1

This is the first edition of a book aiming to fill a gap in the literature on computed tomography (CT). It deals comprehensively with CT examination of the intestinal tract rather than of the solid organs of the abdomen. There are five American and four Belgian contributors whose chapters have been welded into an harmonious whole by editors Professors Megibow and Balthazar of New York University Medical Center.

The book is divided into an introductory chapter on techniques followed by five individual chapters on the oesophagus, stomach, duodenum, small and large bowel. There is a separate chapter on percutaneous drainage of abdominal fluid collections and a final chapter devoted to a series of pathological-radiological correlations of common intestinal diseases. Each of the five chapters forming the bulk of the book follows a similar pattern with detailed sections on indications for CT technique and normal appearances. These are then followed by an account of the diseases to be found in that area.

The CT images are good and generally well labelled, though many could have been reproduced larger if some of the over-generous areas of bare paper had been used. Some of the images are rather grey. There are useful barium studies (usually single contrast) accompanying many of the CT scans and the emphasis throughout the book is on the role of CT alongside the more established techniques of gastrointestinal radiology. Window and level settings are not given.

Each chapter is comprehensively supplied with up-to-date references which are not obtrusive when reading the text.

This should be a valuable book in a developing field of CT which will encourage radiologists to look more critically at their CT images of the GI tract. The emphasis on meticulous technique, particularly the use of air insufflation, and attention to the bowel wall thickness and the relationship of the bowel to the adjacent structures, should enhance the reader's personal expertise to the benefit of patients. The chapter on percutaneous drainage is detailed and offers advice on most drainage problems one can imagine. It will encourage radiologists to make this valuable technique available to their colleagues.

The philosophy that "because a patient pays a substantial sum of money for this examination, *all* information available should be obtained" (p. 31) is commendable even though in Britain one would substitute "the district" for "a patient". It is a reflection of the very positive approach in the book to the value of gastrointestinal CT, though not at the expense of impartiality.

The book is well bound and printed (though with more spelling mistakes than usual in a book of this quality) and should withstand the frequent use it deserves to have in every department with a CT scanner. I can thoroughly recommend it.

A. H. Chalmers

Atlas of Ultrasonographic Artifacts and Variants. By Roger C. Sanders, pp. x + 156, 1986 (Year Book Medical Publishers Inc, Chicago), £62.00.
ISBN 0-8151-7535-3

An atlas of normal variants is always going to be appreciated by those in training. This short text of approximately 150 pages devotes a chapter to the normal variants of most parts of the body. Each image is accompanied by a short caption and line diagram where appropriate. Numerous references are also provided. For the most part, the images are of good quality and clearly explained. Quite a number of images however have been obtained with the static B scanner and will be of little help to those currently training with real-time equipment. Equally unhelpful are the black on white images rather than the conventional white on black format. One or two controversial statements are made in the text—for example, Fig. 109 implies that the arcuate artery needs to be calcified before it is seen, which is untrue, and Fig. 120 states that mild dilatation of the common bile duct is a normal variant in an elderly patient which is not something I have observed among the elderly patients I have scanned. I am not sure that metallic clips or air in the biliary tree should be considered normal variants. Despite these criticisms, I think the book is valuable and a useful addition to the libraries of training centres and to relatively inexperienced ultrasonographers.

M. Phelan

1987, *The British Journal of Radiology*, *60*, 1211–1214 DECEMBER 1987

Infantile recurrent sialectatic parotitis: the role of sonography and sialography in diagnosis and follow-up

By L. Rubaltelli, M.D., T. Sponga, M.D., F. Candiani, M.D., F. Pittarello, M.D. and *M. Andretta, M.D.

Department of Radiology and *Otorhinolaryngology Clinic of the University of Padua, Via Giustiniani, 2—1 35128 Padua, Italy

(*Received November 1986*)

ABSTRACT

The results of a clinical, sonographic and sialographic study in 10 children (aged 4–10 years) with recurrent sialectatic parotitis are presented. Alteration in the sonographic pattern of the parotid glands, consisting of multiple hypoechogenic areas in the parenchyma, were found in four cases; milder non-homogeneity was seen in four cases, and an almost normal pattern in two cases. Sonographic follow-up in two children showed a parallel reduction in non-homogeneity with symptomatic improvement. A probable therapeutic action following sialography using fat-soluble contrast medium was observed in four of the 10 children. The familial nature of the disease, which has not previously been described, is documented.

Recurrent swelling of the salivary gland may have several causes, but in children the most frequent is recurrent sialectatic parotitis (RSP). This condition is characterised by unilateral or bilateral recurrent swelling of the salivary glands, which may last for a few days or, less commonly, several weeks. It is associated with parotid pain and minimal systemic upset. There is no local lymphadenopathy (Blatt, 1966; Wagenaar, 1973). It typically presents in young children, and symptoms usually disappear spontaneously after puberty (Konno & Ito, 1979). Pathological findings comprise pseudocystic dilatation of the interlobular ducts, periductal lymphocytic infiltration, interacinar fibrosis, and a varying degree of fibrosis and atrophy of the glandular acini (Sprinkle, 1968). The aetiology of RSP is not yet known.

Sonography has long been employed in the identification and diagnosis of parotid masses (Gooding, 1980), but its diagnostic role in inflammatory parotid disease has not yet been defined. The aim of this study was to establish the contribution of sialography and parotid sonography in the diagnosis and follow-up of RSP.

MATERIALS AND METHODS

Ten children (seven male, three female, age 4–10 years) who presented with the typical clinical features of RSP for at least 3 years were selected for this study. In addition to routine blood chemistry investigations and periodic ear, nose and throat examinations, all children underwent sialography (during remission), bilateral parotid sonography and pancreatic sonography. Assays were performed for serum and salivary immunoglobulins, autoantibodies and circulating immunocomplexes. Clinical examination and sonographic follow-up were performed 12–18 months after sialographic examination. Linear and convex 5 MHz short-focus transducers (General Electric RT 3000, Ansaldo AUC 940) were used and seven children were also examined with a small-parts 10 MHz transducer (Diasonics). In addition to studying parotid gland size and structure, the sonographic examination was extended to exclude local lymphadenopathy.

Sialographic investigation was carried out using 19–25 G needles with bevelled tips to instil the contrast medium. Satisfactory opacification was achieved with 1–1.5 ml of fat-soluble contrast medium (Ultrafluid Lipiodol). Progression of the contrast medium was followed fluoroscopically and spot radiographs were taken. In most cases, oblique and lateral projections were obtained.

RESULTS

Physical examination did not reveal any abnormality of the oral mucosa or the opening of Stenson's duct in any of the patients. In all cases, sialography demonstrated widespread alteration of gland morphology, with cystic dilatation of minor ducts; the diameter and course of the main duct appeared normal. Cystic dilatations in most of the patients (seven cases) were distributed evenly throughout the gland, giving an "apple tree" picture (Fig. 1.). In three cases there were more obvious abnormalities consisting of localised ductal dilatations distributed irregularly in the parenchyma. No correlation was found between these diverse sialographic features and the clinical severity of the disease.

Sonographic studies in four cases showed marked changes in glandular structure, with multiple hypoechogenic areas within the parenchyma, only in part due to ductal dilatation (Fig. 2A). In the other six patients, the findings were either normal or were of slight non-homogeneity in the parenchyma (Fig. 2B). The salivary glands were consistently enlarged during the acute phase, but of normal size during remission. In addition, the sonographic studies excluded the presence of any discrete mass and sialographic investigation excluded the presence of calculi and congenital malformation in every case.

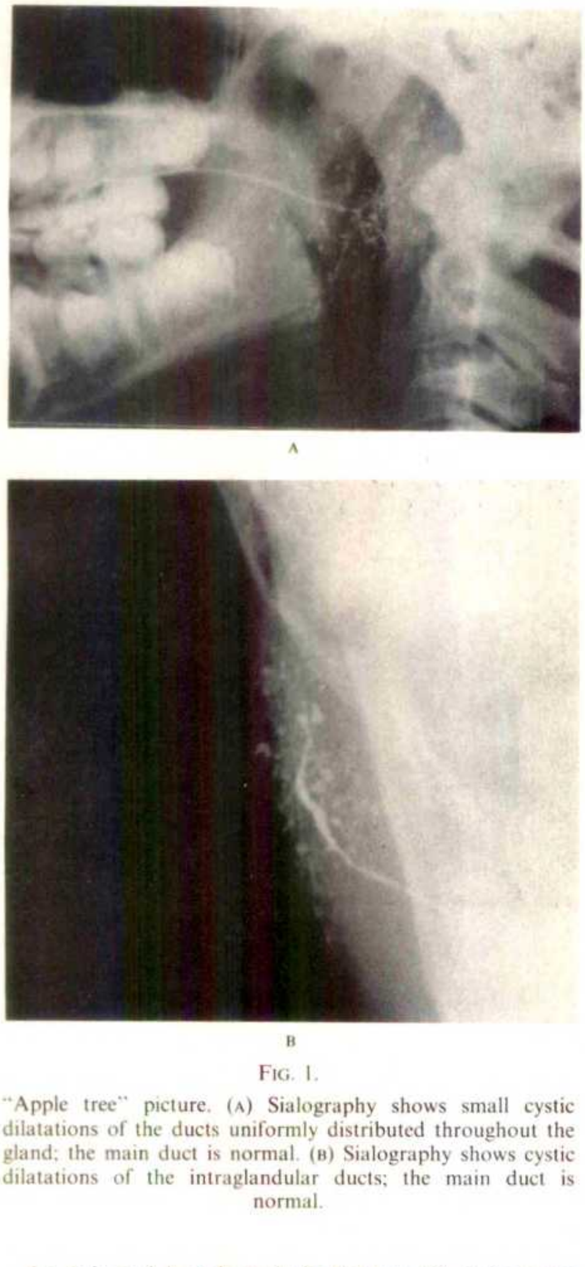


FIG. 1.

"Apple tree" picture. (A) Sialography shows small cystic dilatations of the ducts uniformly distributed throughout the gland; the main duct is normal. (B) Sialography shows cystic dilatations of the intraglandular ducts; the main duct is normal.

An enlarged lymph node in the parotid region was found in one case; the patient had concomitant tonsillitis.

Sonographic studies of the pancreas were normal in every case.

In four cases there was complete remission of symptoms 10–18 months after sialographic examination. Our immunological studies did not confirm the hypothesis of an immune pathogenesis in RSP, as suggested in the literature (Blatt, 1964).

In a survey of the families of the 10 children under investigation, we found a positive history for RSP in the father, grandmother and two brothers of one of our patients; symptoms had disappeared spontaneously in the father at 14 years of age. On parotid sialography the father had the characteristic "apple tree" picture (Fig. 3). The mother of another patient also reported three episodes of parotitis during her childhood; two were without pyrexia and lasted only a few days.

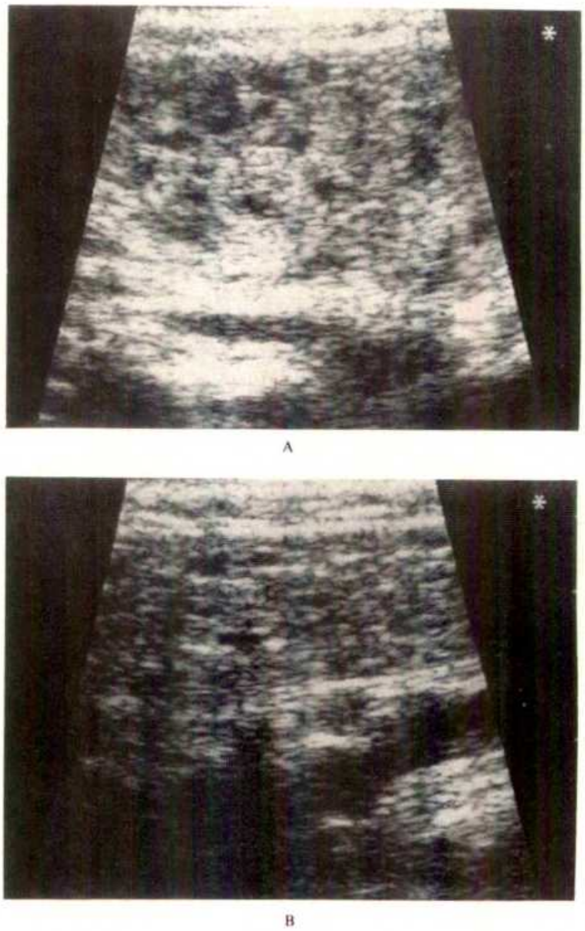
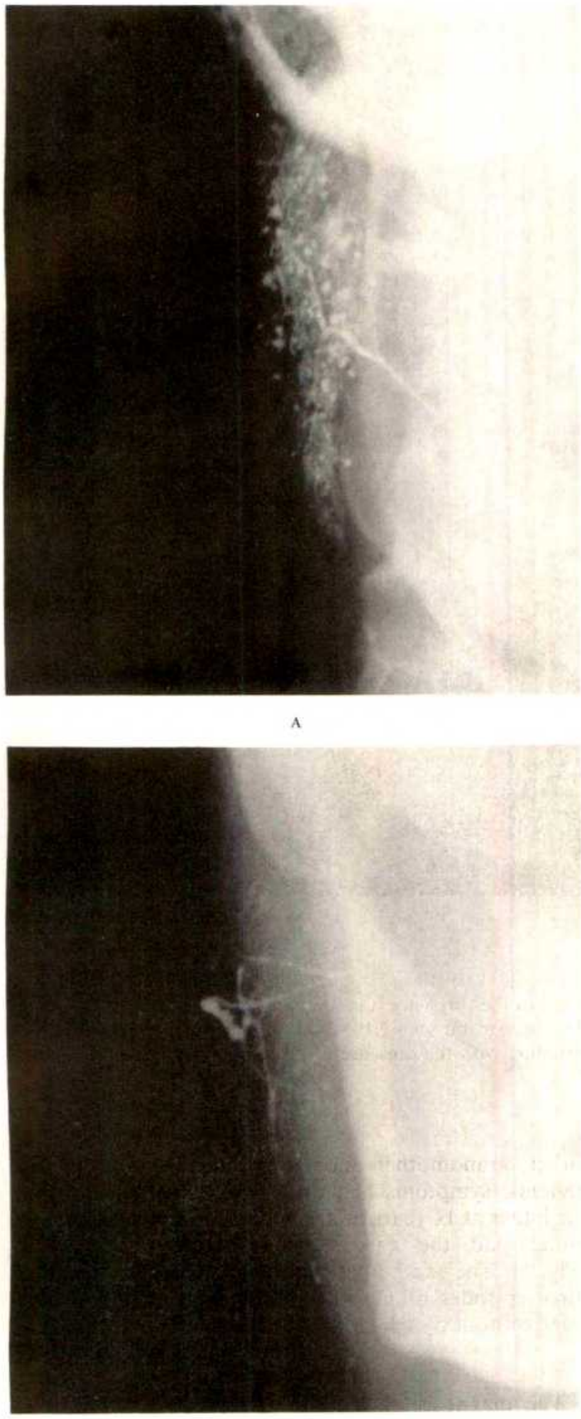


FIG. 2.

(A) Saggital parotid scan (10 MHz). Irregular gland structure due to the presence of multiple hypoechogenic areas. (B) Sagittal parotid scan (10 MHz). A moderately irregular gland structure with the presence of occasional small hypoechogenic areas.

DISCUSSION

The diagnosis of recurrent sialectatic parotitis has always been based on the sialographic findings of an "apple tree" sialogram in the presence of the clinical picture described above. In the cases described, sialography has characteristically shown cystic dilatations of the intraglandular ducts, which probably constitute a permanent pathological injury, as demon-

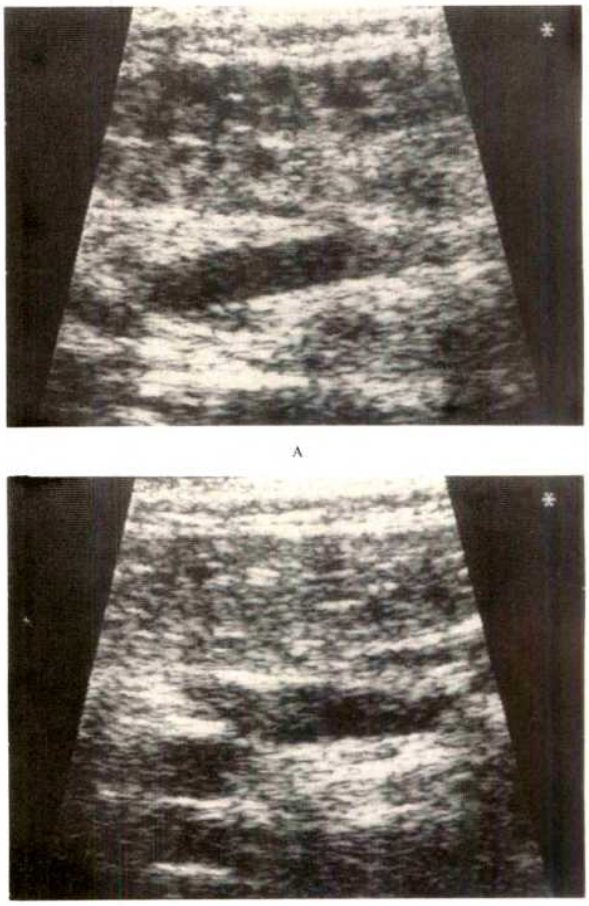


A

B

FIG. 3.

Sialography. (A) An "apple tree" appearance in a 10-year-old boy and (B) the persistence of small cystic dilatations of the intraglandular ducts in his 64-year-old father, who had similar symptoms as a child.



A

B

FIG. 4.

Sagittal parotid scan (10 MHz). (A) Wide intraglandular hypoechogenic areas. (B) Almost complete disappearance after 8 months, concomitant with symptom remission.

strated by their persistence in the father of one of our patients many years after the symptoms had disappeared.

The hypothesis that the cystic dilatations might be congenital was excluded by the demonstration that they appear at different times on each side as the disease progresses (Donzelli et al, 1980). Long-term persistence of the ductal dilatations, and the fact that their uniform or irregular intraglandular distribution is not correlated with the clinical course of the disease, leads us to believe that although sialography is useful for the diagnostic confirmation of RSP, it does not provide prognostic information, and thus is not an appropriate follow-up procedure in these patients, as suggested by other workers (Blatt, 1964).

Sonography was carried out in each patient as a first-line examination to exclude the presence of a mass within the parotid. In so doing, widespread alterations of sonographic pattern were noted in four patients, and in each case this finding coincided with the acute episode of the disease; follow-up in two of these cases showed that the abnormalities decreased (Fig. 4).

On the basis of these results, which require further confirmation, we believe that the finding of sonographic abnormality with multiple hypoechogenic areas in the presence of the characteristic clinical picture may indicate RSP; sialography plays an important role in confirming this diagnosis, and is essential for the diagnosis in the presence of equivocal or normal sonographic examination. The presence of major sonographic abnormalities in patients with more severe recurrent episodes, and their tendency to subside as demonstrated in two cases, suggests that follow-up of the disease and the effects of therapy are best monitored by this procedure.

The remission of recurrent episodes following sialography in four patients who, prior to referral, had been treated with antibiotics, steroids, and anti-inflammatory agents without effect, deserves comment. These patients had experienced acute episodes approximately every 3 months, but at 10–18 months following sialographic study, symptomatic remission was maintained. This observation suggests that sialography with Ultrafluid Lipiodol played a therapeutic role, for which several interpretations are possible: the mechanical effect of introducing the fat-soluble contrast medium may be therapeutic together with its viscosity which permits the contrast material to remain in the ductal system for several days.

Sonographic studies of the pancreas in children with RSP were considered appropriate in view of reports (Dreiling et al, 1978) that the salivary glands and the pancreas show a parallel response to harmful agents. In our series, however, the pancreas showed normal architecture on sonography in every case.

Lastly, the possible familial tendency of RSP is noteworthy. This hypothesis, previously advanced but never confirmed, is supported by our finding of a positive family history in two groups, and documented by the presence of persistent sialographic abnormalities in the father of one of our patients.

ACKNOWLEDGMENT

The authors thank Dr D. M. Hansell for his co-operation and help in the translation of the work.

REFERENCES

BLATT, J. M., 1964. On sialectasis and benign lymphosialadenopathy (the pyogenic parotitis, Gourgerot-Sjögren's syndrome, Mikulicz's disease complex). A ten-year study. *Laryngoscope, 74*, 1684–1699.

——1966. Chronic and recurrent inflammations of the salivary glands with special reference to children. *Laryngoscope, 76*, 917–933.

DONZELLI, F., COLLESELLI, P., CHIARELLI, S. M., NARNE, S., CLEMENTI, M., LAVERDA, A. M. & ZACCHELLO, F., 1980. La parotite ricorrente scialectasica nell'infanzia: studio di 10 casi. *Rivista Italiana di Pediatria, 6*, 613–619.

DREILING, D. A., NORONHA, M., NACCHIERO, M., PIERONI, P. & WOLFSON, P., 1978. The parotid and the pancreas. *American Journal of Gastroenterology, 70*, 627–634.

GOODING, G. A. W., 1980. Gray scale ultrasound of the parotid gland. *American Journal of Roentgenology, 134*, 649–472.

KONNO, A. & ITO, E., 1979. A study on the pathogenesis of recurrent parotitis in childhood. *Annals of Otology, Rhinology and Laryngology, 63*, 1–20.

SPRINKLE, F. M., 1968. Recurrent salivary gland disease. *Laryngoscope, 78*, 654.

WAGENAAR, J., 1973. Chronic recurrent parotitis in children. *Archivium Chirurgicum Neerlandicum, 23*, 13.

1987, *The British Journal of Radiology*, *60*, 1215–1219

The effect of oral magnesium-containing bowel preparation agents on mucosal coating by barium sulphate suspensions

By *B. G. Conry, M.R.C.P., D.M.R.D., F.R.C.R., †S. Jones, B.Sc., M.P.S. and C. I. Bartram, F.R.C.P., F.R.C.R.

Departments of Diagnostic Radiology and †Pharmacy, St Bartholomew's Hospital, West Smithfield, London EC1A 7BE

(*Received October 1986 and in revised form March 1987*)

ABSTRACT

Alteration in the quality of mucosal coating by barium sulphate suspension observed during double-contrast barium enema (DCBE) examinations when an oral magnesium-containing purgative (Picolax) was used as sole bowel preparation has been investigated *in vivo*. Small amounts of Picolax were found to produce a linear increase in apparent viscosity and thixotropy, due to flocculation. The effect of equivalent concentrations of acid was significantly less ($p < 0.01$), and of magnesium chloride was significantly greater ($p < 0.05$), whereas magnesium citrate was comparable to Picolax, demonstrating the deflocculating effect of citrate on the flocculating action of magnesium ions. It is suggested that colonic residue from orally ingested magnesium-containing purgatives may contain sufficient magnesium ions to increase viscosity of the barium suspension and visibly affect its coating during DCBE.

Bowel preparation for barium enema usually involves a combination of dietary restriction and purging, often with the addition of cleansing water enemas. Picolax (Nordic Pharmaceuticals) combines the osmotic purgative effect of magnesium citrate with the direct-contact irritant action of sodium picosulphate. Picolax has been recommended for use without cleansing water enemas as a satisfactory method of bowel preparation for double-contrast barium enemas (DCBE) (De Lacey et al, 1982).

While investigating this claim (Bartram et al, 1984), it was noted that there was a considerable difference in the behaviour of the barium suspension with various bowel preparations. A suspension constituted with a given volume of water to be satisfactory for use after water enemas, became extremely viscous when used after Picolax without a cleansing water enema. In addition it did not flow freely and produced an irregular thick coating (Fig. 1).

This was thought initially to be a function of dehydration. Water enemas leave the colonic surface wet, needing a more viscous suspension for adequate coating whereas, without a water enema, the colon would be drier and the same suspension too viscous for ideal flow characteristics. However, this did not explain several observations. Picolax seemed to increase the viscosity of the suspension even after water enemas had been given, and two sachets made more difference than one. Also, changes in the suspension occurred rapidly, usually only in the proximal colon, the suspension behaving more normally in the distal colon.

These findings suggested a possible interaction between Picolax and the barium suspension, due to retention of part of the oral dose in the colon. This study was designed to confirm, *in vitro*, that Picolax has a direct effect on the apparent viscosity and thixotropy of barium suspensions, and to determine which constituent of Picolax was responsible.

DEFINITION OF TERMS

Apparent viscosity is a measure of fluid friction and is defined as:

$$\frac{\text{Shear stress}}{\text{Rate of shear}} = \eta \text{ (unit centipoises, cps)}$$

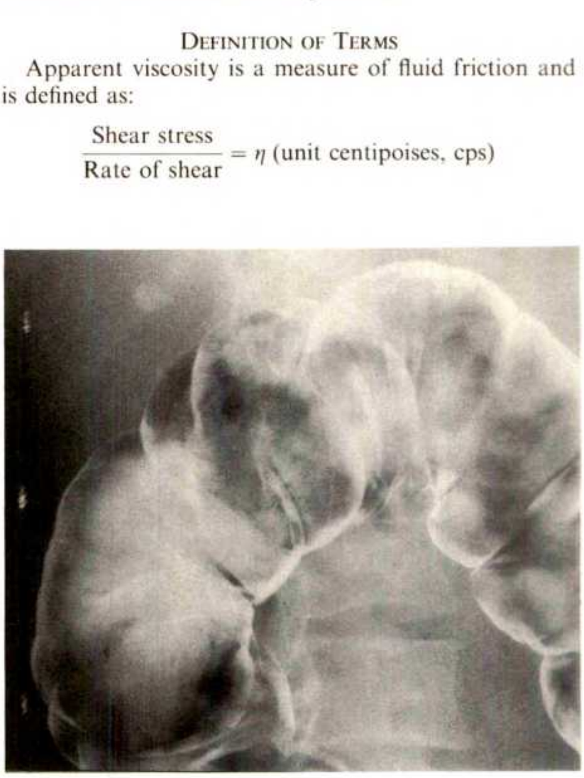


FIG. 1.

Double-contrast view of the hepatic flexure where an increase in the viscosity of the suspension has caused an irregular thick coating.

---

*Author for correspondence. Present address: Pembury Hospital, Pembury, Tunbridge Wells, Kent.

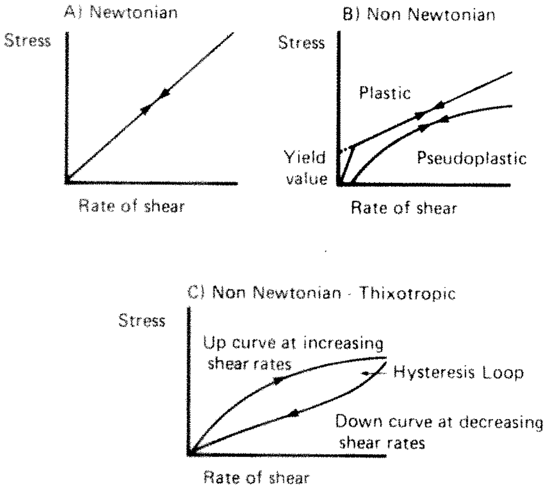


FIG. 2.

Generalised flow curves measured on a rotating viscometer. > = up curve, < = down curve. Note the identical up and down curves in non-thixotropic liquids (A + B). The area between the up and down curves in C form a hysteresis loop.

Simple Newtonian liquids such as water (viscosity 1 cps) have a constant viscosity and flow when a very small force is applied to them. Liquids which require a minimum shear stress (yield value) to be applied to them before the material starts flowing are said to have plastic flow. Pseudoplastic flow is present if the viscosity decreases at higher shear rates. The flow characteristics of barium sulphate suspensions are complex, displaying elements of plastic and pseudoplastic flow as well as thixotropic behaviour (Fig. 2) (Miller & Skucas, 1977a).

Thixotropy means "to change by touch." It arises from the structural breakdown and subsequent build-up of particles in barium sulphate suspensions when different shearing rates and shearing durations are applied (Martin et al, 1964a). There is a difference between the stress readings when the rate of shear is being increased (up curve) and decreased (down curve) using a rotating viscometer. This temporary difference is due to structural breakdown which gradually reforms with consequent return of viscosity to the pre-stressed level. The area of the hysteresis loop formed between the up and down curves is a good quantitative measure of thixotropy (Schott, 1980).

MATERIALS AND METHODS

Each sachet of Picolax contains: sodium picosulphate 10 mg, magnesium oxide 3.5 g, citric acid 12 g and undefined excipients and flavourings. This dissolves in water to form an acidic solution of magnesium citrate and sodium picosulphate. Picolax solutions were prepared according to the manufacturer's instructions to give concentrations of 0.5, 1.0 and 1.5 sachets of Picolax/100 ml distilled water.

Light magnesium oxide (BP grade) and citric acid (Analar grade) were mixed together in the same ratio as that found in Picolax and dissolved in distilled water to give magnesium citrate solutions equivalent to that found in 0.5, 1.0 and 1.5% sachet Picolax solutions. Magnesium chloride (Analar) was dissolved in distilled water to give 8.83% w/v and 17.66% w/v solutions. The concentration of magnesium ions was calculated to be identical to that found in 0.5 and 1.0% sachet Picolax solutions. The acidic effect of Picolax solutions upon barium sulphate suspensions was assessed by using sufficient 0.1 M hydrochloric acid (AVS) to produce the same pH drop as the Picolax solutions.

A single batch of Polibar ACB barium sulphate enema packs (E-Z-EM Co. Ltd) was primarily used for analysis. Suspensions 90% w/v were prepared as for clinical use as follows: 450 ml of distilled water warmed to 37°C was added to a disposable enema pack. The pack was thoroughly shaken to fully wet and mix the powder and then left in a water bath at 37°C for 30 min. After further shaking to resuspend the barium sulphate, 500 ml (90% of the pack) was placed in a 600 ml short-form beaker. When required, test reagent was added and the suspension stirred for 1 min. The pH of the suspension was measured and the suspension placed in a water bath at 37°C. The combinations of suspensions and reagents analysed are summarised in Table I.

Viscosity and thixotropy were determined using a Brookfield Synchro-Lectric rotating viscometer with a No. 2 cylindrical spindle attachment. Torque unit stress readings were recorded for shear produced by spindle rotation at 0.3, 0.6, 1.5, 3.0, 6.0, 12.0, 30.0 and 60.0 r.p.m. in turn and then from 60 down to 0.3 r.p.m. Data analysis was performed on observations between 0.3–12.0 r.p.m. to eliminate torque readings produced either when turbulent flow was observed or which were outside the range of the instrument, both of which sometimes occurred at 30–60 r.p.m. Plots of torque

TABLE I

BARIUM SUSPENSION AND REAGENT COMBINATIONS ANALYSED

Barium suspension	Reagent (10 ml samples)
1 Polibar ACB (90% w/v)	None
2 Polibar ACB (90% w/v)	Picolax
3 Polibar ACB (90% w/v)	Hydrochloric acid equivalent in pH to Picolax + Polibar (Suspension 2) (reflecting the acid content of Picolax alone)
4 Polibar ACB (90% w/v)	Magnesium chloride, equivalent to Mg content of Picolax (reflecting the Mg content of Picolax alone)
5 Polibar ACB (90% w/v)	Magnesium citrate as found in Picolax
6 Baritop G (90% w/v)	None
7 Baritop G (90% w/v)	Picolax

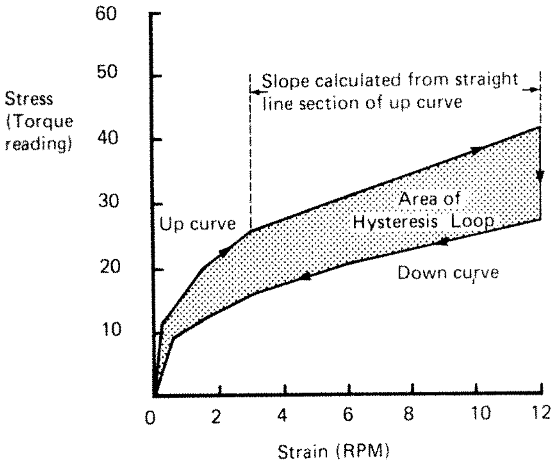


FIG. 3.

Calculation of apparent viscosity and hysteresis loop area for a given sample of barium sulphate suspension with added test solution.

Apparent viscosity (cps) = slope × K, where K = machine constant = 316 for cylinder No. 2.
Thixotropy ∝ area of hysteresis loop.

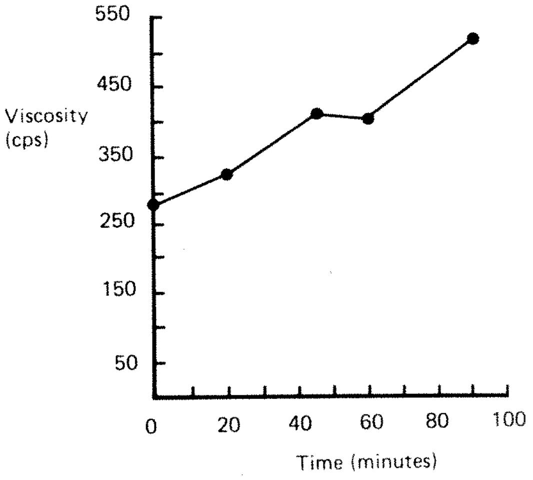


FIG. 4.

Viscosity of Polibar ACB barium sulphate suspension (90% w/v) against time at 37°C.

units against r.p.m. were made which produced the up and down curve of a hysteresis loop. The area of the hysteresis loop was calculated by subtracting the area under the down curve from the area under the up curve (Fig. 3). All plots had the same scale so that the hysteresis loop area of different samples could be directly compared without the necessity of determining the units of the area.

Apparent viscosity in centipoise of each sample was determined from the slope of the linear portion of the up curve between 3 and 12 r.p.m. and the application of a simple formula (Fig. 3). The slope was calculated using linear regression. The correlation coefficient (r) for these calculations was > 0.99. The time taken for sample analysis was about 10 min which, together with sample handling, was kept as constant as possible to ensure a similar shear history for all samples.

Using the computer statistical package MINITAB, the results were first tested for normality and then either analysis of variance or the Mann–Whitney U-test was applied as appropriate. The Picolax results were compared with each of the other reagents at each concentration.

A preliminary experiment showed that for Polibar ACB 90% w/v suspension alone there was an 8% increase in apparent viscosity over the first 10 min (Fig. 4). This was assumed to be due to natural sedimentation and was subsequently found to be insignificant compared with the viscosity changes observed due to the action of the reagents. This effect was minimised by resuspension prior to analysis and the agitative effect of the rotating viscometer.

Bowel absorption of orally administered magnesium is inefficient, less than a third of the normal oral intake of 300–400 mg being absorbed. Indeed, at doses greater than 800 mg absorption falls by a further 30% (Alpers, 1983). Since magnesium ions form the major cation in the total mass of Picolax, the precise amount of reagent used was selected taking this poor gut absorption into account. The 10 ml aliquots of reagent used at concentrations equivalent to 1.0 sachet of Picolax/100 ml represent 5% of the total dose administered to patients receiving two sachets of Picolax prior to DCBE. The magnitude of Picolax was felt to be a conservative estimate of the probable colonic concentration of Picolax at the time of the enema.

To investigate any suspension-dependent response, another powdered suspension, Baritop G (Concept Pharmaceuticals), was analysed. In this case, the apparent viscosity of a 90% w/v Baritop G suspension was determined both before and following the addition of 10 ml portions of a 1% Picolax sachet solution.

RESULTS

Figures 5 and 6 show the apparent viscosity and thixotropy for each reagent plotted against concentration. The stress readings obtained with magnesium chloride at the 1.0%, and for magnesium citrate at the 1.5%, concentration levels were outside the range of the equipment used. A minimum possible apparent viscosity value of 2500 cps was allocated to these data points. It was not possible to determine the thixotropic index at these points.

Picolax was found to increase both the apparent viscosity and thixotropy of the barium sulphate

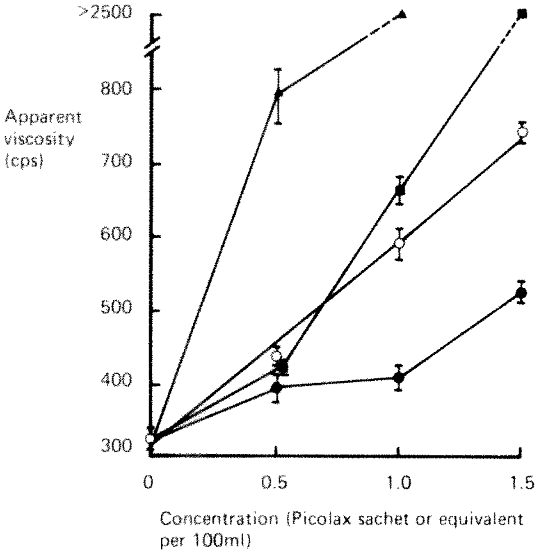


FIG. 5.

Apparent viscosity of Polibar ACB barium sulphate suspension (90% w/v) following the addition of different concentrations of Picolax, acid, magnesium citrate and magnesium chloride solutions. Values plotted are mean ±SEM ($n = 4$). Magnesium chloride and magnesium citrate values outside the range of the equipment are plotted as > 2500 cps (○——○ Picolax. Linear regression analysis gave a correlation coefficient, $r = 0.98$, ●——● acid, ■——■ magnesium citrate, ▲——▲ magnesium chloride).

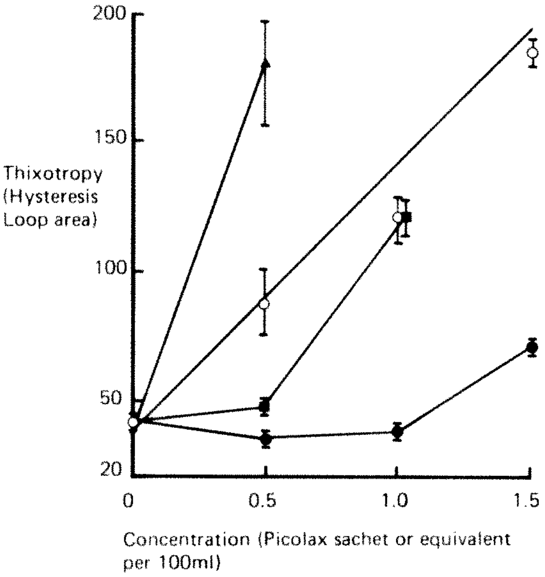


FIG. 6.

Thixotropy of Polibar ACB barium sulphate suspension (90% w/v) following the addition of different concentrations of Picolax, acid, magnesium citrate and magnesium chloride solutions. Values plotted are mean ±SEM ($n = 4$). It was not possible to obtain values for magnesium citrate at the 1.5 concentration level and for magnesium chloride at the 1.0 and 1.5 concentration levels. (○——○ Picolax. Linear regression analysis gave a correlation coefficient, $r = 0.95$, ●——● acid, ■——■ magnesium citrate, ▲——▲ magnesium chloride).

suspension. A good correlation between Picolax concentration and apparent viscosity and thixotropy was obtained ($r = 0.98$ and 0.95 respectively).

The addition of acid produced a slight increase in viscosity at all concentrations but only increased thixotropy at the 1.5% concentration level, significantly lower than the changes for Picolax ($p < 0.01$).

Magnesium chloride had a dramatic effect on the barium sulphate suspension. Both apparent viscosity and thixotropy were greatly increased and at a significantly higher level than for Picolax ($p < 0.05$).

The addition of magnesium citrate increased both apparent viscosity and thixotropy, results being broadly similar to those obtained with Picolax. With magnesium citrate, the 0.5% and 1.0% apparent viscosity results and 1.0% thixotropy results were not significantly different from those with Picolax, differences at other levels being probably due to a combination of factors including the excipients in Picolax and experimental error.

Flow studies with Baritop G, which has previously been shown to display pseudoplastic behaviour (Anderson et al, 1980), also demonstrated that addition of small concentrations of Picolax produced an increase in apparent viscosity (Fig. 7).

DISCUSSION

Thixotropy is an important property in barium flow and coating so that the barium sulphate remains suspended when agitation or stirring is stopped (Miller & Skucas, 1977b). Barium sulphate enemas are formulated to produce "controlled" flocculation so that they are suitably thixotropic (Miller & Skucas, 1977c). Flocculation of a suspension describes the clustering together of particles into flocs, which in turn are held in aggregates producing a structural network. Excessive flocculation is undesirable, leading to changes in the internal structure and so altering the rheological properties of the suspension. Simultaneous increases in viscosity and thixotropy are good evidence of flocculation (Martin et al, 1964b).

Picolax dissolves into an ionic and acidic solution, the main ionic constituents of which are magnesium and citrate. Traces of electrolytes can affect the rheology of simple barium sulphate suspensions. Small divalent ions such as magnesium exert a greater influence upon the rheology than monovalent ions (Miller & Skucas, 1977d). Citrate is a known deflocculating agent (Embring & Masttsson, 1968). Thus, there is evidence that the components of Picolax

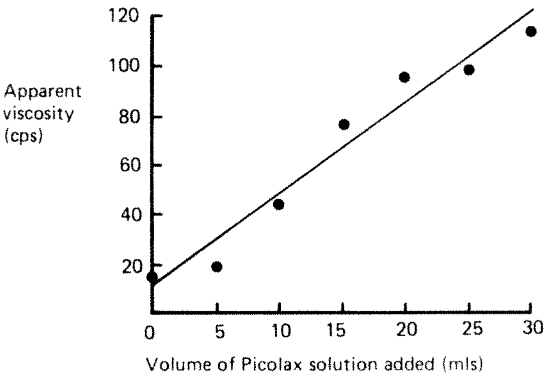


FIG. 7.

Apparent viscosity of Baritop G barium sulphate suspension (90% w/v) following the addition of Picolax solution (1 sachet/100 ml). Values plotted are single determinations only. Linear regression analysis gave a correlation coefficient, $r = 0.98$.

can affect the rheological properties of barium sulphate suspensions.

The results show that small amounts of Picolax produce an increase in apparent viscosity and thixotropy of Polibar ACB. This indicates that Picolax causes flocculation of barium sulphate suspensions *in vitro*. The effect of acid was found to be significantly less than that of Picolax, proving that the acidity of Picolax alone was not responsible for the observed rheological changes.

The magnesium chloride solutions produced very pronounced flocculation of the suspension, while the magnesium citrate results were similar to those of Picolax. Thus, it can be concluded that the magnesium ions in Picolax were responsible for the flocculation, but that this effect was moderated by the presence of citrate ions. The increasing viscosity noted with Baritop G 90% w/v showed that the rheological effects of Picolax were not confined to a single type of barium sulphate suspension.

Oral magnesium is incompletely absorbed in high concentration. It is therefore likely that residual Picolax may be found in the colon in concentrations similar to those used in this study. Small doses of magnesium-containing purgatives, such as Picolax, have been shown to produce a profound effect on the rheology of barium sulphate suspensions. Magnesium ions have been identified as the ionic group responsible for the alteration in the flow characteristics of the suspensions, the effect being moderated by the presence of citrate. The colonic residue of orally ingested magnesium-containing purgatives has therefore the potential to alter the behaviour of barium sulphate suspensions, and should be considered when mucosal coating problems are encountered. The contact of barium suspensions with magnesium ions should not, however, be regarded as totally deleterious. A slight "gel" effect, with minimal increase in viscosity and thixotropy can improve mucosal adherence and result in improved coating (Brown, 1981). Magnesium in the correct amount may therefore be beneficial.

Two practical consequences emerge from this study. When barium is reconstituted with warm water the suspension will increase in viscosity if left to stand. A short vigorous shake however, immediately prior to use will restore the original viscosity. Any detrimental effect from retained magnesium ions in the proximal colon can be offset by making the initial suspension less viscous, by adding an extra 50 ml of water. This is recommended when magnesium-containing agents are used as the sole means of bowel preparation.

ACKNOWLEDGMENTS

The authors would like to thank Mr A. Johnson for his assistance in producing the computer graphics used to calculate the thixotropic index, Ms P. Patel for her help in performing the statistics and Ms N. Herrera for typing the manuscript.

REFERENCES

ALPERS, D. H., 1983. Absorption of water soluble vitamins, folate minerals and vitamin D. In *Gastrointestinal Disease: Pathophysiology, Diagnosis, Management*. Ed. by M. H. Sleisenger and J. S. Fordtran (W.B. Saunders, Philadelphia), pp. 840–841.

ANDERSON, W., HARTHILL, J. E., JAMES, W. B. & MONTGOMERY, D., 1980. Barium sulphate preparations for use in double contrast examination of the upper gastrointestinal tract. *British Journal of Radiology, 53*, 1150–1159.

BARTRAM, C. I., MOOTOOSAMY, I. M. & LIM, K. H., 1984. Washout versus non-washout (Picolax) preparation for double contrast barium enemas. *Clinical Radiology, 35*, 143–146.

BROWN, G. R., 1981. *The magnesium citrate–bisacodyl colon preparation: final report and twenty year experience*. 11th Annual Meeting of the Society of Gastrointestinal Radiologists.

DE LACEY, G., BENSON, M., WILKINS, R., SPENCER, J. & CRAMER, B., 1982. Routine colonic lavage is unnecessary for double contrast barium enema in outpatients. *British Medical Journal, 284*, 1021–1022.

EMBRING, G. & MASTTSSON, O., 1968. Barium contrast agents. *Acta Radiologica Diagnosis, 7*, 245–256.

MARTIN, A. N., BANKER, G. S. & CHUN, A. H. C., 1964a. Rheology. In *Advances in Pharmaceutical Sciences*. Ed. by H. S. Bean., A. H. Beckett & J. E. Carless (Academic Press, London), Vol. 1, pp. 16–17.

——1964b. *ibid.*, p. 60.

MILLER, R. E. & SKUCAS, J., 1977a. Basic properties of barium sulphate. In *Radiographic Contrast Agents*. Ed. by R. E. Miller and J. Skucas (University Park Press, Baltimore), pp. 30–32.

——1977b. *ibid.*, p. 85.

——1977c. *ibid.*, pp. 98–99.

——1977d. *ibid*, p. 28.

SCHOTT, H., 1980. Rheology. In *Remington's Pharmaceutical Sciences*. Ed. by J. P. Remington (Mack Publishing, Easton), p. 331.

Book review

Plain X-ray Diagnosis of the Acute Abdomen. By Malcolm H. Gough, Michael W. L. Gear and Abdallah S. Daar, pp. viii+203, 1986 (Blackwell Scientific Publications, Oxford), £27.50.
ISBN 0-632-01432-6

This is the second edition of a book first published in 1971 aimed to be a practical guide to the interpretation of the plain abdominal radiograph and intended for the casualty officer or trainee surgeon. Mr A. S. Daar, a transplant surgeon, has joined Messrs Gough and Gear, general surgeons, as a joint author for the second edition.

The book outlines about 100 pathological conditions and normal variations in a standard format, listing the radiographic appearances, the radiological differential diagnosis, clinical presentation and differential diagnosis. I find it amazing that a multi-author book on plain radiograph radiological diagnosis of the acute abdomen should not have a radiologist as a joint author; indeed, there is no acknowledgment to any radiological contribution at all. The radiological aspects of this book are poor and result from the lack of radiological input.

During the introduction, a scheme for the systematic examination of the plain abdominal radiograph is suggested, starting with the bones, which in my experience is virtually never useful in the acute situation. Gas shadows and abnormal opacities, which I would regard as of major importance in the acute abdomen, are relegated to the third and fourth areas of the systematic examination. The description of the radiological appearances is superficial and usually inadequate. The radiological differential diagnoses are often appalling, clearly reflecting the lack of radiological input, *e.g.* included in the differential diagnosis of a calcified pancreas in chronic pancreatitis (which demonstrates a band of small pancreatic calcifications extending from the right to the left of the spine in the distribution of the pancreas) are calcified aortic aneurysm, nephrocalcinosis and adrenal calcification! A good example of a sigmoid volvulus, with a marked generalised distension of the large bowel in addition to the sigmoid loop, includes caecal volvulus in the differential, but excludes pseudo-obstruction. Indeed, caecal and sigmoid volvuli are often linked together in differential diagnoses, implying that they cannot be separated from their plain radiograph appearances.

Pseudo-obstruction is discussed without any mention of the value of barium studies to help exclude organic obstruction, but is hardly ever mentioned in the differential diagnosis of the many radiographs showing dilated small and large bowel. In the differential diagnosis of medullary sponge kidney, chronic pyelonephritis and renal cortical necrosis are wrongly included and the inclusion of a calcified abdominal aortic aneurysm seems bizarre. These examples comprise just a few of the errors present in the radiological descriptions and differential diagnoses. As expected, the brief descriptions of the clinical presentation and clinical differential diagnosis are generally good.

The general layout of the book is poor with large amounts of wasted space, radiographs poorly cropped, some poorly reproduced and often occupying only part of an otherwise empty page. In many instances, the blacked-out name marker in the corner of the radiograph could have been excluded without any loss of diagnostic information. Another annoying feature is the use of similar arrows on a radiograph each pointing out a different feature, or an arrow pointing out a feature which was not the main point of the radiograph but an incidental finding. Figure 6 demonstrates a radiograph labelled "left lateral erect film" which is in fact a right lateral decubitus and the opposite decubitus to that normally taken to demonstrate a small pneumoperitoneum.

This book perpetuates many of the myths about plain abdominal radiographs reproduced in so many older textbooks of radiology and surgery. There is an apparent lack of awareness of the many scientific publications on the subject, both recent and old, which have disproved a number of the quoted traditional opinions. Although the clinical aspects of this book are sound, the poor radiological features, layout, labelling and some poor reproductions mean that I cannot recommend it.

S. Field

1987, *The British Journal of Radiology*, 60, 1221–1222 DECEMBER 1987

Effect of cirrhosis on accuracy of $^{99}Tc^{m}$-tin colloid scintigraphy and ultrasound scanning in diagnosis of hepatocellular carcinoma

By *P. Powell-Jackson, M.D., M.R.C.P., A. Forbes, B.Sc., M.R.C.P., †M. Michell, M.B., F.R.C.R. and ‡Roger Williams, M.D., F.R.C.P.

Liver Unit and †Department of Radiology, King's College Hospital and King's College School of Medicine and Dentistry, Denmark Hill, London SE5 9RS

(*Received February 1987 and in revised form March 1987*)

ABSTRACT

The effect of cirrhosis on the accuracy of ultrasonography and scintigraphy in the diagnosis of hepatocellular carcinoma (HCC) has not been established. We have therefore studied the findings on ultrasound and scintigraphy in four groups of patients. Fourteen had HCC and cirrhosis, 13 had HCC but no cirrhosis, 53 had cirrhosis but no HCC and 31 had evidence neither of cirrhotic nor malignant liver disease. The accuracies of a positive interpretation of HCC on ultrasound and scintigraphy in the absence of cirrhosis were 85% and 66% respectively (NS), but fell (significantly in the case of scintigraphy: $p < 0.05$) to 80% and 31% respectively in the presence of cirrhosis ($p < 0.01$). The poorer performance of scintigraphy in the presence of cirrhosis was a result both of its lower sensitivity (50% compared with 85%) and the greater frequency of false positives (28% vs 5%: $p < 0.001$). The accuracy of a negative interpretation of HCC on scintigraphy in the absence of cirrhosis was 96% but fell to 84% in the presence of cirrhosis, whereas on ultrasound it remained the same (96%). In conclusion, we recommend ultrasound in preference to scintigraphy as a more accurate technique for the diagnosis of HCC in the presence of cirrhosis.

Although ultrasound scanning and scintigraphy are the two most widely available and commonly used non-invasive techniques for imaging the liver, the effect of cirrhosis on the accuracy of the two techniques in diagnosing hepatocellular carcinoma (HCC) has not previously been established. In the absence of cirrhosis, the sensitivity and specificity of ultrasound in diagnosing hepatic tumours were superior to those with scintigraphy in some series (Smith et al, 1976; Cosgrove & McCready, 1978; DeRivas et al, 1980) but not in others (Snow et al, 1979; Smith et al, 1982). In the presence of cirrhosis, the sensitivity and specificity of scintigraphy are generally inferior to those of ultrasound (Maringhini et al, 1984; Shinagawa et al, 1984), but in none of these series was the accuracy of the normal and abnormal observations ascertained because of the lack of appropriate control groups. In the present study we have included such control groups and have been able to determine the effect of cirrhosis on the accuracy of the two techniques in diagnosing hepatocellular carcinoma.

PATIENTS AND METHODS

The patients studied comprised four groups: (i) 14 patients with HCC and cirrhosis; (ii) 13 with HCC but no evidence of chronic liver disease; (iii) 53 with cirrhosis and no HCC; (iv) 31 with neither cirrhotic nor malignant liver disease (Table I). Histological confirmation of each diagnosis was obtained by liver biopsy within 4 weeks of the scanning procedures. The absence of HCC was confirmed in each case by prolonged follow-up (minimum 9 months) or at autopsy in those dying earlier. The ultrasound scans and scintigrams were carried out and reported on by several radiologists without knowledge of the histology or other scan result.

Ultrasound was carried out using a real-time sector scanner (Diasonics DRF1) using a 3.5 MHz probe. $^{99}Tc^{m}$-tin colloid scintigraphy was performed with a nuclide dose of 80 MBq: three views (anterior, posterior

TABLE I

DIAGNOSIS FOR THE PATIENTS IN EACH OF THE FOUR GROUPS STUDIED

	No. of patients
Group 1. HCC and cirrhosis	14
Group 2. HCC without cirrhosis	13
Group 3. Cirrhosis without HCC	53
Alcoholic	14
Chronic active hepatitis	9
Primary biliary cirrhosis	8
Secondary biliary cirrhosis	2
Alpha-1 antitrypsin deficiency	1
Cryptogenic	19
Group 4. Non-cirrhotic liver disease	31
Alcoholic hepatitis	6
Acute hepatitis	14
Reactive hepatitis	4
Venous outflow obstruction	3
Primary biliary cirrhosis (Stage 1/2)	3
Non-cirrhotic portal hypertension	1

---

*Present address: Department of Health Care of the Elderly, Dulwich Hospital, London SE22.

‡Author for correspondence.

TABLE II

Effect of cirrhosis on accuracy of ultrasound and scintigraphy in the diagnosis of HCC

	HCC/no cirrhosis		HCC + cirrhosis	
	Ultrasound	Scintigraphy	Ultrasound	Scintigraphy
True positive (sensitivity)	12/13 (92%)	12/13 (92%)	12/14 (85%)	7/14 (50%)
False positive	2/31 (6%)	6/31 (19%)	3/53 (5%)	15/53 (28%)
True negative (specificity)	29/31 (93%)	25/31 (80%)	50/53 (94%)	38/53 (71%)
False negative	1/13 (7%)	1/13 (7%)	2/14 (14%)	7/14 (50%)
Accuracy of positive interpretation	12/14 (85%)	12/18 (66%)	12/15 (80%)	7/22 (31%)
Accuracy of negative interpretation	29/30 (96%)	25/26 (96%)	50/52 (96%)	38/45 (84%)

and right lateral) were recorded using either an IGE or an Elscint CE-1 gamma camera (350 000 counts per view). Hepatocellular carcinoma was suggested on ultrasound by the presence of single or multiple space-occupying lesions with altered reflectivity in comparison with the remainder of the liver parenchyma, and on scintigraphy by the appearance of single or multiple areas of impaired uptake of isotope. Particular efforts were made to distinguish between focal (countable) lesions and the generally poor, patchy uptake of cirrhosis.

Statistical analysis was from the standard error of difference between proportions.

Results

Cirrhosis had a profound effect on the accuracy of a positive interpretation of HCC determined by scintigraphy, but not by ultrasound (Table II). On scintigraphy, the accuracy fell from 66% to 31% ($p < 0.05$), whereas on ultrasound it fell only from 85% to 80% (NS). The poorer performance of scintigraphy in the presence of cirrhosis was due to the much greater frequency of false positives (28% compared to 5%: $p < 0.001$) and to the lower sensitivity of scintigraphy compared with ultrasound (50% compared to 85%). The effect on the accuracy of a negative interpretation of HCC was much less marked. On scintigraphy, the accuracy fell from 96% to 84% (NS) and on ultrasound it remained at 96%.

Discussion

The presence of cirrhosis had a marked effect on the accuracy of scintigraphy because of the difficulty in differentiating the areas of poor isotope uptake due to tumour from those due to cirrhosis. Although this problem is present to a certain extent with ultrasound, it is usually possible to distinguish the abnormal echogenicity of tumour from that of cirrhosis. Furthermore, ultrasound differentiates tumour from other space-occupying lesions such as abscesses and cysts.

In the absence of cirrhosis, we have shown the sensitivity and specificity of ultrasound to be similar to those of scintigraphy. In the presence of cirrhosis we have shown, like others (Maringhini et al, 1984; Shinagawa et al, 1984), that the sensitivity and specificity of ultrasound are superior to those of scintigraphy but the absence of suitable control groups had not permitted these previous investigators to evaluate the accuracy of either technique. We are now able to recommend ultrasound in preference to scintigraphy as a more accurate technique for diagnosing HCC in the presence of cirrhosis. The sensitivity of scintigraphy, unlike that of ultrasound, becomes disproportionately poor as the size of the tumour diminishes (Shinagawa et al, 1984) and, as a means of screening for the early development of HCC in cirrhosis, ultrasound should be the imaging technique of first choice.

REFERENCES

Cosgrove, D. O. & McCready, V. R., 1978. Diagnosis of liver metastases using ultrasound and isotope scanning techniques. *Journal of the Royal Society of Medicine, 71,* 652–657.

DeRivas, L., Coombes, R. C., Gazet, J-C., Ford, H. T., Neville, A. M. & Powels, T. J., 1980. Tests for liver metastases in breast cancer. Evaluation of liver scan and liver ultrasound. *Clinical Oncology, 6,* 225–230.

Maringhini, A., Cottone, M., Sciarrino., E., Marcenò, M. P., Seta, F. L., Rinaldi, F. & Pagliaro, L., 1984. Ultrasonographic and radionuclide detection of hepatocellular carcinoma in cirrhotics with low alphafetoprotein levels. *Cancer, 54,* 2924–2926.

Shinagawa, T., Ohto, M., Kimawura, K., Tsunetomi S., Morita, M., Saisho, H., Tsuchiya, Y., Saotome, N., Karasawa, E., Miki, M., Veno, T. & Okuda, K., 1984. Diagnosis and clinical features of small hepatocellular carcinoma with emphasis on the utility of real-time ultrasonography. *Gastroenterology, 86,* 495–502.

Smith, I. E., Taylor, K. J. W., McCready, V. R., Powles, T. J. & Bondy, P. K., 1976. A comparison of grey scale ultrasound with other methods for the detection of liver metastases from breast carcinoma. *Clinical Oncology, 2,* 47–53.

Smith, T. J., Kemeny, M. M., Sugarbaker, P. H., Jones, A. E., Vermess, M., Shawker, T. H. & Edwards, B. K., 1982. A prospective study of hepatic imaging in the detection of metastatic disease. *Annals of Surgery, 195,* 486–491.

Snow, J. H., Goldstein, H. M. & Wallace, S., 1979. Comparison of scintigraphy, sonography and computed tomography in the evaluation of hepatic neoplasms. *American Journal of Roentgenology, 132,* 915–918.

1987, *The British Journal of Radiology*, 60, 1223–1226 DECEMBER 1987

Case reports

The association of post-radiation thyroid nodular disease with compensated hypothyroidism

By *I. Doniach, M.D., F.R.C.Path., F.R.C.P., †J. E. Kingston, B.Sc., M.R.C.P., ‡P. N. Plowman, M.D., M.R.C.P., F.R.C.R. and †J. S. Malpas, D.Phil., F.R.C.P., F.R.C.R.

Departments of Histopathology, †Paediatric Oncology and ‡Radiotherapy, St. Bartholomew's Hospital, West Smithfield, London EC1A 7BE

(*Received May 1987*)

In a comprehensive survey of the literature on the effects of ionising radiation on the human thyroid gland, Maxon et al (1977) found that the majority of thyroid neoplasms reported following external irradiation had occurred after doses not exceeding 20 Gy. This fits the concept that a dosage of 30 Gy or more would be likely to sterilise the thyroid follicular cells and render the gland atrophic rather than neoplastic. However, during the past decade, the development of thyroid neoplasia, particularly papillary carcinoma, has been described after 40–50 Gy external irradiation to the neck in the treatment of malignant disease (McDougall et al, 1980; Petronius et al, 1982; Rosen et al, 1984). The development of subclinical or overt hypothyroidism is also documented, as indicated by a compensatory rise in the level of circulating thyroid stimulating hormone (TSH) (Constine et al, 1984). Thus the development of thyroid neoplasia in these circumstances can be regarded to result from irradiation initiated carcinogenesis promoted by the TSH-induced hyperplasia of surviving non-sterilised follicular cells.

Judging from the findings in a similar situation in experimental rats one would expect the development of multiple tumours in the thyroid gland (Doniach, 1956; Lindsay et al, 1961). In fact, multiple tumours and multinodularity of the human thyroid gland have been reported after therapeutic external irradiation of the neck, by Doniach et al (1966), McKenzie and Hope-Stone (1975), McDougall et al (1980) and Petronius et al (1982). Petronius and colleagues noted an elevated level of TSH in their patients.

CASE REPORT

We report here the history and findings in a boy who had therapeutic external beam irradiation for a laryngeal sarcoma at the age of 20 months and who subsequently underwent thyroidectomy for a multinodular gland at the age of 14 years. A series of thyroid function tests, including numerous TSH assays, was carried out during the intervening period and this has allowed us a unique opportunity to study the serum levels of the neoplasia-promoting agent, TSH, in the years leading up to the clinical presentation of thyroid nodularity.

History

In June 1974, this male infant aged 20 months presented with a 3 week history of wheeze, increasing dyspnoea and snoring. There was a past history of cow's milk intolerance and eczema but no other serious illness. On examination the infant was tachypnoeic with widespread inspiratory rhonchi and with sternal recession. He failed to respond to bronchodilator therapy and laryngoscopy revealed a solid (2 cm × 3 cm), pedunculated tumour in the region of the left arytenoid. Following tracheostomy, subtotal excision of a tumour arising from the left aryepiglottic fold was undertaken. It was not possible to remove the base of the tumour. Histological examination of the resected polypoid mass showed a malignant spindle-cell tumour with large strap-like cells with cross striations characteristic of an embryonal rhabdomyosarcoma. No evidence of distant metastatic spread was detected. Following surgery, a course of radical external beam radiotherapy, 52 Gy in 30 fractions over 58 days, was given to the larynx using parallel opposed cobalt portals with 30 Gy to the regional cervical lymph nodes. The initial portals (which included the regional nodes) measured 6 cm × 9 cm; the boost portals (Fig. 1) measured 4 cm × 6 cm and, as can be seen from the portal radiography, encompassed the thyroid gland

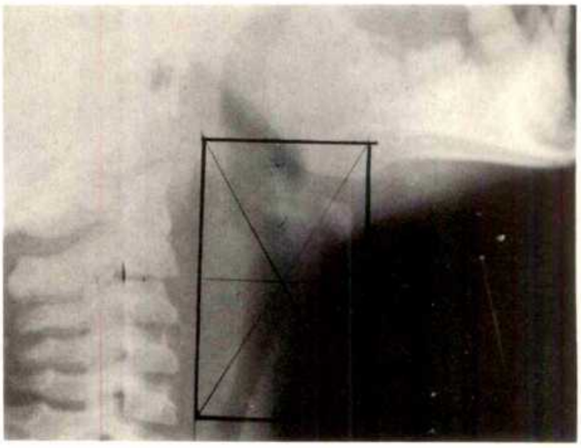


FIG. 1.

The lateral cobalt radiation portal (4 cm × 6 cm) used to deliver the boost of 22 Gy to the primary region, after a larger portal had delivered 30 Gy to this area and the regional nodes.

---

*Author for correspondence.

TABLE I

THYROID FUNCTION TESTS

Date	Treatment	T_4 (nmol/l)	T_3 (nmol/l)	THUT (units)	FTI (units)	TSH (mU/l)
June 1974	Resection of tumour					
June 1974	Radiotherapy					
June 1974–May 1975	Chemotherapy					
23.2.77		74	1.16	112	69	>25.0
5.10.77		63		126	53	25.0
7.6.78		68	1.99	116	62	
10.5.79		68	2.03	115	62	>50.0
2.1.80		81	2.30	119	71	48.3
3.9.80		87		123	74	38.7
25.3.81		80		114	74	14.9
31.3.82		74	2.78	117	66	18.6
7.8.86		74		116	67	12.1
27.10.86	R hemithyroidectomy	71		112	66	7.1
6.11.86	100 μg T_4/day	65		111	61	47.0
20.11.86		106		107	104	2.7
2.12.86	L hemithyroidectomy					
6.12.86		112		111	106	14.5
10.12.86	150 μg T_4/day					
18.12.86		124		103	126	1.9
23.12.86		127		106	127	0.7

T_4 = thyroxine (normal range 58–174 nmol/l).
T_3 = triiodothyronine (normal range 1.07–3.18 nmol/l).
THUT = thyroid hormone uptake test (normal range 92–118 units).
FTI = free thyroxine index (normal range 58–174 units).
TSH = thyroid stimulating hormone (normal range 0.4–5.0 mU/l).

which therefore received the full 52 Gy. Adjuvant chemotherapy with cyclophosphamide, vincristine and actinomycin-D was given at 3-week intervals over a period of one year.

An examination under anaesthetic in June 1975, at the end of treatment, showed no evidence of residual disease. Thereafter, the child has remained well with no signs of recurrent disease. From 1975 onwards the boy was noted to have a raised TSH level although his serum thyroxine remained within the normal range (Table I). He defaulted from follow-up between 1982 and 1986 and, when seen for review in August 1986, 12 years following his radiation treatment, a firm nodule was detected in the lower part of the right lobe of the thyroid gland. An ultrasound scan showed that this was a solid mass and a right hemithyroidectomy was undertaken. Following this, he was commenced on thyroxine supplements, 100 μg daily, and after 4 weeks the remaining thyroid tissue was excised. Results of the thyroid function tests and details of the pathology of the resected thyroid gland are discussed below.

Thyroid function tests

The levels of thyroxine (T_4) all lie towards the lower limit of the normal range until thyroxine was administered daily from November 6, 1986. The levels of triiodothyronine (T_3) rise to the middle of the normal range and continue to rise as seen in compensated hypothyroidism. The levels of thyroid hormone uptake test (THUT) are in the high normal range and exceed it on October 5, 1977, indicating hypothyroidism. The levels of free thyroxine index (FTI) lie towards the lower limit of the normal range and are below it on October 5, 1977.

The levels of TSH show gross hypersecretion from at least 3 years to 6 years post-radiotherapy and then a gradual fall as the resultant thyroid hyperplasia compensated by an increase in T_4 and T_3 secretion. Nevertheless, the levels of TSH were still somewhat raised 12 years post-radiotherapy when the clinical nodule presented. It is also interesting to note the steep rise in TSH following the initial hemithyroidectomy, indicating the low reserve of thyroid tissue, and a similar but less marked rise after the second hemithyroidectomy. This later increase in TSH occurred despite the administration of thyroxine supplements, 100 μg of T_4 daily, commenced after the initial hemithyroidectomy.

Pathology

Right hemithyroidectomy specimen. This was a small thyroid lobe 4.5 cm × 2.0 cm × 1.5 cm and isthmus 1.6 cm × 0.8 cm × 0.5 cm of total weight 5 g, the cut surface of which showed numerous nodules ranging from a few millimetres to 1.3 cm in diameter. Microscopic examination showed that almost the whole parenchyma was replaced by nodules of varying size and morphology, many of them surrounded by a thick layer of dense fibrous tissue. The nodules were variously macrofollicular, microfollicular and solid alveolar. Some showed numerous papillary infoldings. In the majority of nodules, the follicles were lined by tall epithelium. The cells in one nodule, arranged in mixed microfollicles and solid alveoli, contained crowded, misshapen nuclei, a few of which were empty-looking and resembled those seen in papillary carcinoma. It is not possible to be dogmatic that this is a focus of papillary carcinoma, though it is a

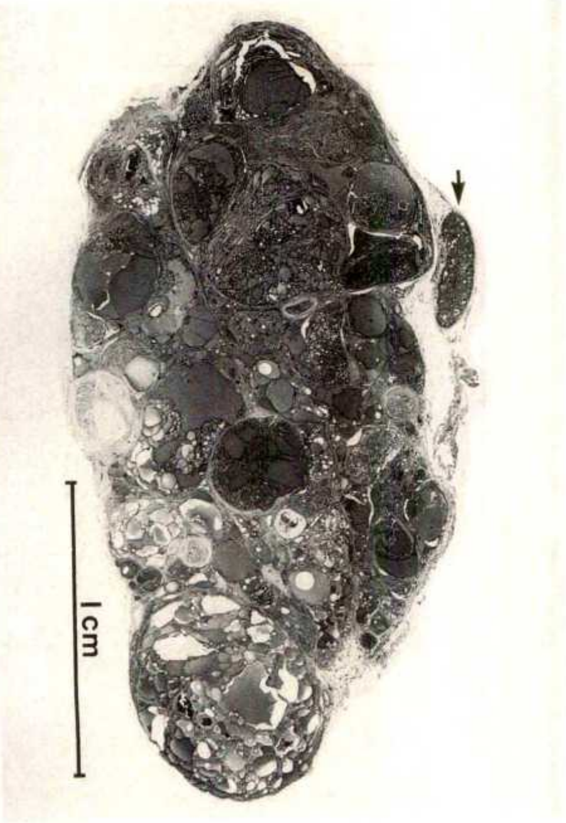


FIG. 2.

Longitudinal section of the left lobe of thyroid gland stained with haematoxylin and eosin. The parenchyma is totally replaced by multiple nodules that vary in size and morphology. The arrow points to the attached parathyroid.

reasonable possibility. There was a small discrete portion of parathyroid gland made up of clear cells, embedded within the periphery of the thyroid.

Left hemithyroidectomy specimen. This was a small thyroid lobe 2.5 cm × 2.0 cm × 1.0 cm, the cut surface of which again showed numerous nodules. Microscopic examination (Fig. 2), revealed similar overall appearances to those of the right lobe except that the nodules showed more colloid accumulation and the follicular epithelium of the nodules was, in general, much flatter. There was a minute focus of cells with one psammoma body embedded in fibrous tissue resembling those seen in solid areas of papillary carcinoma. Again, it is not possible to be dogmatic about the diagnosis. A small parathyroid gland made up of clear cells, indicated in Fig. 2, was attached to the outside of the thyroid capsule.

The microscopic findings are similar to those described in the previous reports of radiation-induced thyroid dysgenesis, quoted in the introduction. The small size of the thyroid gland, in spite of its nodularity, and the marked fibrosis indicate the gross loss of parenchyma resulting from the previous irradiation. In fact, the shrinkage of the gland makes it possible to differentiate the pathology from other causes of nodularity such as iodine deficiency, antithyroid drug treatment and familial dyshormonogenesis. Since the cells of both normal and hyperplastic tissues may develop bizarre-shaped, highly abnormal nuclei after irradiation, it can be very difficult to diagnose malignancy confidently in the absence of infiltration or metastasis. The small size of the two parathyroids and their content of clear cells, indicating active secretion, suggest that they too had been damaged and were showing compensatory hyperactivity.

DISCUSSION

The points of interest in this case are the dosage of radiation absorbed by the thyroid gland, the nature of the pathology and the serial documentation of biochemical hypothyroidism with persistently elevated TSH levels.

In a survey of 22 patients given 40–50 Gy of therapeutic radiation to the head and neck, 12 of whom subsequently developed thyroid carcinoma and six of whom developed thyroid adenomas, Rosen et al (1984) concluded from dosimetric considerations of the radiotherapy in each of these patients, that the thyroid gland had not been in the primary beam and consequently that the absorbed dose to the thyroid was under 25 Gy in each case. The patient described here undoubtedly received 52 Gy to the thyroid gland and it is of interest in this regard that the thyroid gland was able to undergo the multinodular changes demonstrated in Fig. 2, which Rosen et al (1984) predict to be associated with lower radiation doses. Similarly, the carcinoma arose after this dose and, indeed, we have encountered at least three cases of carcinoma of the thyroid occurring after mantle irradiation which, in our centre, gives the thyroid an absorbed dose of 35 Gy.

The histopathology of the thyroid showing replacement of the parenchyma by fibrosis and multiple nodules of varied morphology parallels the findings of previous reports. This fits the concept of hyperplasia and neoplasia induced by maintained TSH stimulation of surviving irradiated follicular cells. It is difficult to differentiate focal hyperplasia from adenoma in endocrine organs on purely morphological grounds, hence the growing custom of labelling them as all "nodules".

Many authors have discussed the need for prophylactic thyroid medication after high-dose irradiation that includes the thyroid gland in the field (Fuks et al, 1976; Constine et al, 1984; Rosen et al, 1984). In the report by Constine et al (1984), a spontaneous return to normal was seen in 20 of 75 children with elevated TSH levels following irradiation of the neck for Hodgkin's disease. It is of interest that the TSH levels in our patient started to fall again after 6 years, despite his higher dose of radiotherapy. However, if, as seems likely, maintained elevated levels of TSH promote the development of thyroid neoplasia, the administration of thyroxine supplements to children with persistently elevated TSH levels after therapeutic external irradiation of the neck would appear to be sensible, even if this compromises the spontaneous recovery of T_4 secretion described by Constine et al (1984).

It would appear eminently reasonable to monitor

1987, *The British Journal of Radiology*, *60*, 1226–1227

thyroid function, including TSH levels, and to administer thyroxine supplements when subclinical or compensated hypothyroidism develops, thus removing the promoting carcinogenic action of TSH stimulation. This may not affect the follicular cell division of normal growth of the thyroid in childhood, nor the reparative hyperplasia that occurs surrounding any damaged parenchymatous foci, as both of these types of growth are TSH-independent in the experimental animal (Logothetopoulos, 1963; Williams and Doniach, 1963).

It is unknown whether the cytotoxic chemotherapy played an additive or synergistic role with the radiation-initiated carcinogenesis; although there is evidence for such synergism in the development of acute non-lymphocytic leukaemia following Hodgkin's disease (Canellos et al, 1975). It is likely that thyroxine supplementation at an earlier stage in this case would have prevented the development of the thyroid nodularity.

ACKNOWLEDGMENTS

We thank members of the Department of Chemical Endocrinology for carrying out the numerous thyroid function tests and Mr W. S. Shand for his surgical expertise.

REFERENCES

CANELLOS, G. P., DE VITA, V. T., ARSENAU, J. C., WHANG-PENG, J. & JOHNSON, R. E. C., 1975. Second malignancies complicating Hodgkin's disease in remission. *Lancet*, 947–950.

CONSTINE, L. S., DONALDSON, S. S., MCDOUGALL, I. R., COX, R. S., LINK, M. & KAPLAN, H. S., 1984. Thyroid dysfunction after radiotherapy in children with Hodgkin's disease. *Cancer*, *53*, 878–883.

DONIACH, I., 1956. comparison of the carcinogenic effect of X-irradiation with radioactive iodine on the rat's thyroid. *British Journal of Cancer*, *11*, 67–76.

DONIACH, I., EADIE, D. G. A. & HOPE-STONE, H. F., 1966. The development of multiple thyroid adenomata in primary hyperthyroidism in previously irradiated thyroid glands. *British Journal of Surgery*, *53*, 681–685.

FUKS, Z., GLATSTEIN, E., MARSA, G. W., BAGSHAW, M. A. & KAPLAN, H. S., 1976. Long-term effects of external radiation on the pituitary and thyroid glands. *Cancer*, *37*, 833–841.

LINDSAY, S., SHELINE, G. E., POTTER, G. D. & CHAIKOFF, I. L., 1961. Induction of neoplasms in the thyroid gland of the rat by X-irradiation of the gland. *Cancer Research*, *21*, 9–16.

LOGOTHETOPOULOS, J., 1963. Growth and function of the thyroid gland in rats injected with L-thyroxine from birth to maturity. *Endocrinology*, *73*, 349–352.

MCDOUGALL, I. R., COLEMAN, C. N., BURKE, J. S., SAUNDERS, W. & KAPLAN, H. S., 1980. Thyroid carcinoma after high-dose external radiotherapy for Hodgkin's disease. *Cancer*, *45*, 2056–2060.

MCKENZIE, C. G. & HOPE-STONE, H. F., 1975. Multiple adenomas of the thyroid occurring 20 years after successful radiotherapy for neuroblastoma in the cervical lymph-nodes. *British Journal of Radiology*, *18*, 1028–1031.

MAXON, H. R., THOMAS, S. R., SAENGER, E. L., BUNCHER, C. R. & KERIAKES, J. G., 1977. Ionizing irradiation and the induction of clinically significant disease in the human thyroid gland. *American Journal of Medicine*, *63*, 967–978.

PETRONIUS, H. T., KATIKINENI, M., KINSELLA, T. J., BARSKY, S. H., BRENNAN, M. F., CHU, E. W. & ROBBINS, J., 1982. Thyroid nodules after high dose external radiotherapy. *Journal of the American Medical Association*, *47*, 3217–3220.

ROSEN, I. B., SIMPSON, J. A. & SUTCLIFFE, S., 1984. High-dose radiation and the emergence of thyroid nodular disease. *Surgery*, *96*, 988–994.

WILLIAMS, E. D. & DONIACH, I., 1963. Thyroid autografts in hypophsectomised and in thyroxine treated rats. *Journal of Endocrinology*, *6*, 479–488.

Skin reaction following aminoglutethimide and radiotherapy

By D. S. Williams, M.B., B.Ch. and M. D. Leslie, B.Sc., M.R.C.P.

Department of Radiotherapy & Oncology, The Royal Free Hospital, Pond Street, Hampstead,
London NW3 2QG

(*Received May 1987*)

We describe a case in which an enhanced skin reaction occurred in a patient started on aminoglutethimide. The patient had 2 months previously received orthovoltage radiotherapy.

CASE REPORT

A 61-year-old woman underwent a right mastectomy and axillary clearance for Stage I carcinoma of the breast. Three years later, she complained of back pain and a bone scan showed the presence of widespread metastatic lesions. She was treated with tamoxifen (20 mg b.d.) and local radiotherapy, using cobalt 60 gamma rays, was given to the lower dorsal spine to a total dose of 3600 cGy in nine fractions over 11 days. She responded well and remained asymptomatic for 5 months until a pathological fracture of the right clavicle occurred. The fracture site was irradiated with 300 kV X-rays in five fractions over 5 days to a total dose of 2000 cGy. The skin covered by the radiation portal at this site showed an initial brisk erythema which settled within 2 weeks of finishing radiotherapy, leaving only minimal residual hyperpigmentation of the skin.

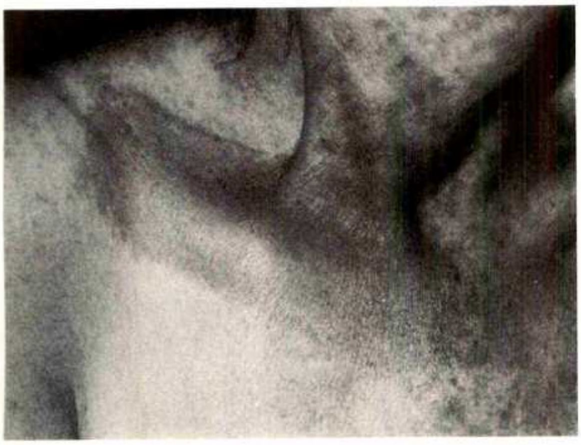


FIG. 1.

Photograph showing erythema of the previously irradiated skin over the right clavicle.

Two months later the patient developed pain in the right hip and a large lytic lesion was seen in the right neck of the femur. Radiotherapy was started to the hip, but a pathological fracture developed, requiring internal fixation. After the operation, radiotherapy was completed using cobalt 60 γ rays. A dose of 3040 cGy midplane was given in nine fractions over 11 days, using a parallel pair technique.

Tamoxifen was stopped and treatment with aminoglutethimide (250 mg b.d.) and hydrocortisone (20 mg b.d.) was commenced. After 10 days she became unwell and feverish with a generalised maculo-papular pruritic rash. In addition, marked erythema of the previously irradiated skin over the right clavicle was seen (Fig. 1). This corresponded to the orthovoltage radiotherapy treatment field of 2 months previously, but the other areas which had been treated with megavoltage irradiation showed no such reaction.

Aminoglutethimide was stopped and the generalised rash as well as the rectangular area of erythema over the clavicle disappeared in 4 days. She was started on medroxyprogesterone acetate (100 mg t.d.s.) and no undue side-effects occurred. She has mobilised well and currently has no evidence of progressive metastatic disease.

DISCUSSION

Early radiation changes in skin include dilatation of blood vessels and other signs of acute inflammation reflecting acute tissue injury. The walls of dermal vessels become infiltrated with fibrin; later, a characteristic concentric proliferation of intimal fibrous tissue is seen (endarteritis obliterans) and large bizarre fibrocytic nuclei are present. Late pathological effects include persistent melanin pigmentation and vascular dilatation.

Aminoglutethimide produces a "medical adrenalectomy" and is an established form of hormonal treatment in metastatic carcinoma of the breast (Ashbury et al, 1981). A known side-effect is the development of a maculo-papular rash in 7% of cases which may resolve without withdrawal of the drug (Calabresi & Parks, 1985). The mechanism of production of the rash is not fully known but a lupus erythematosus-like syndrome has been described (McCraken et al, 1980).

In our patient, a typical rash developed in response to the drug, but in addition there was an enhanced reaction in the skin which had received orthovoltage irradiation 2 months previously. The other areas of palliative irradiation were all treated with megavoltage radiation and thus there would have been skin sparing.

A tentative explanation for the reaction may be that although the erythematous phase of the acute radiation reaction resolved, permanent depletion of various stem-cell lines within the irradiated skin occurred (Fowler, 1968). This effect, we suggest, would reduce the tolerance of the skin to further insult, whatever its nature. This would be dose-dependent and therefore in this case the orthovoltage treated area of skin which would have received the highest skin dose was particularly susceptible to the subsequent rash. A similar mechanism may underly the so-called "recall reaction" in which an erythematous reaction, similar to the primary radiation reaction, occurs only in a previously irradiated area, after the introduction of cytotoxic chemotherapy (Hellman, 1985).

ACKNOWLEDGMENTS

We would like to thank Dr L. F. Senanayake for his permission to report this case, and Dr C. H. Collis for his helpful comments.

REFERENCES

ASHBURY, R. F., BAKEMEIR, R. F., FOLSCH, E., MCCUNE, C. S., SAVLOV, E. & BENNETT, J. M., 1981. Treatment of metastatic breast cancer with aminoglutethimide. *Cancer, 47*, 1954–1958.

CALABRESI, P. & PARKES, R. E., 1985. In *The Pharmacological Basis of Therapeutics, 7th edit*. Ed. by A. G. Gilman, L. S. Goodman, T. W. Rall & F. Murad (MacMillan), pp. 1294.

FOWLER, J. F., 1968. Effects of fractionated radiation on the skin of pigs and other animals and on tumours in rats. In *Dose Rate in Mammalian Radiation Biology*. Proceedings of a symposium, Oak Ridge UT-AEC (Conf. 680410), pp 21.1–21.25.

HELLMAN, S., 1985. In *Cancer, Principles and Practice of Oncology, 2nd edit*. Ed. by V. T. De Vita, S. Hellman & S. A. Rosenburg (J. B. Lipincott, Philadelphia), pp. 241–242.

MCCRAKEN, M., BENSON, E. A. & HICKLING, P., 1980. Systemic lupus erythematosus induced by aminoglutethimide. *British Medical Journal, 281*, 1254.

1987, *The British Journal of Radiology*, *60*, 1228–1229

An unusual cause of haemobilia

By *Wolfgang Dock, M.D., *Florian Grabenwöger, M. D., *Gerhard Bardach, M.D., *Fritz Pinterits, M.D., †Walter Klepetko, M.D. and †Günter Laufer, M.D.

*Department of Radiology of the †Second Clinic of Surgery, University of Vienna Hospitals, Allgemeines Krankenhaus Wien, Austria

(*Received December 1986 and in revised form March 1987*)

Haemobilia, a communication between blood vessels and the biliary tract, is usually secondary to trauma, vascular disease, inflammatory disorders, gallstones or tumours (Hirsch et al, 1982). An extremely rare cause is presented, namely tuberculosis, presumably related to erosion of the hepatic artery and formation of a pseudoaneurysm.

CASE REPORT

A 16-year-old girl was admitted with haematemesis and melaena. The patient had been well until the age of 14 years, when she experienced symptoms of fever, night sweats and fatigue and was diagnosed as having pneumonia.

Two years later, she experienced sudden onset of severe right upper abdominal pain and was treated with analgesics and spasmolytics. One week later symptoms recurred with haematemesis and melaena. Laparotomy revealed a large, blood-filled gallbladder and a dilated, blood-filled common bile-duct. She was transferred to the University of Vienna Hospital in a state of shock with a systolic pressure of 70 mm/Hg and a pulse rate of 130 per min.

Laboratory findings revealed a haematocrit of 19% and 7.2 g/dl haemoglobin. Alkaline phosphatase and gamma-GT were slightly elevated (443 U/l and 69 U/l). Plain radiography of the abdomen showed multiple calcifications consistent with lymph nodes, and endoscopy showed a large amount of blood in the duodenum. Ultrasound revealed extremely dilated extra- and intrahepatic bile ducts; the gallbladder wall was thickened and filled with echogenic material. Medial to the common bile duct was an echo-free 4 cm cavity displacing the common bile duct dorsally (Fig. 1). Angiographically, a cavity 4 cm in diameter was seen lying adjacent to the common hepatic artery as well as to the common bile duct (Fig. 2).

At repeat laparotomy, a large pseudoaneurysm was found arising from the common hepatic artery with erosion into the common bile duct. The common hepatic artery was ligated proximal and distal to the pseudoaneurysm, which was excised. Histologically, the wall of the resected pseudoaneurysm contained caseous material with epithelioid cell formations and lymphocyte infiltrations. A Ziehl–Neelsen strain demonstrated acid-fast bacilli. The final diagnosis was erosion of the common hepatic artery by caseous lymph-nodes from tuberculosis with formation of a pseudoaneurysm and perforation into the common bile duct.

Six weeks later a control angiogram was performed which showed sufficient collateral perfusion of the liver primarily from the left gastric artery (Fig. 3). By this time the patient was completely asymptomatic.

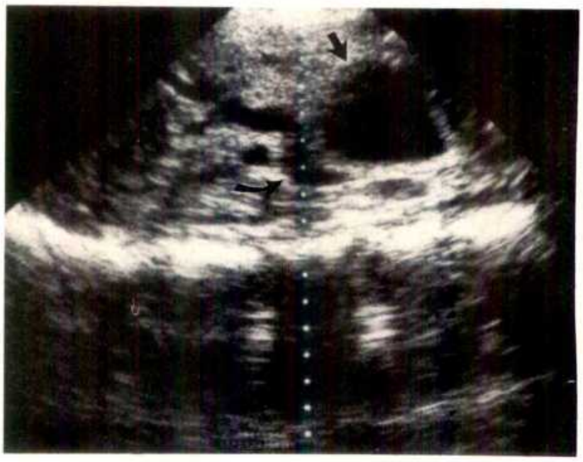


FIG. 1.

Sonogram of the liver (transverse section): dilated extra- and intrahepatic bile ducts. Pseudoaneurysm of the common hepatic artery (arrow) displacing the common bile duct dorsally (curved arrow).

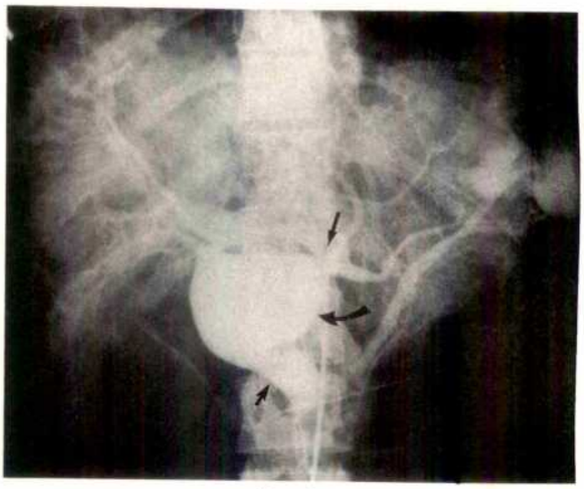


FIG. 2.

Selective angiogram of the coeliac trunk: site of perforation of the common hepatic artery (long arrow) filling the pseudoaneurysm (curved arrow) and the common hepatic bile duct (short arrow). Atrophic spleen with large accessory spleen (confirmed at laparotomy).

Address for correspondence: Wolfgang Dock, M.D., Radiological Department of the Second Clinic of Surgery, Spitalgasse 23, A1090 Vienna, Austria.

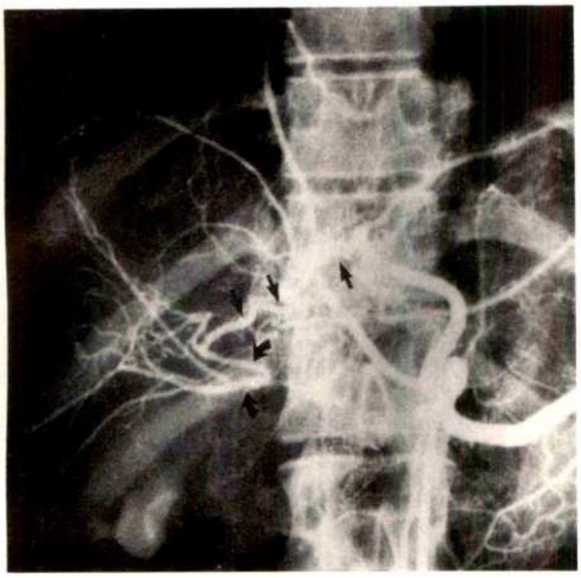


FIG. 3.

Selective control angiogram after 6 weeks: sufficient perfusion of the liver from collaterals (straight arrows) filling the branches of the hepatic artery (curved arrows).

DISCUSSION

The word haemobilia is defined as bleeding into the biliary tract. The most common cause is trauma (blunt or iatrogenic, for example after liver biopsy or percutaneous biliary drainage). Inflammatory or vascular disorders are less common whereas gallstones or tumours are rare causes of haemobilia. Among the inflammatory causes, mycotic aneurysm with perforation into the biliary tract is by far the most common. Haemobilia as a complication of a lymph node tuberculosis of the abdomen, to our knowledge, has been reported only twice (Thompson, 1928; Sheridan, 1956).

Clinically, a triad of symptoms is characteristic: (1) biliary colic, (2) jaundice, and (3) gastrointestinal bleeding (Bismuth, 1973; Chen et al, 1983). Colic and jaundice are caused by intermittent obstruction of the bile duct with blood clots. The bleeding may be slow and intermittent, leading to melaena and chronic anaemia, or rapid and massive, leading to haematemesis and shock (Chen et al, 1983). Selective coeliac, hepatic and superior mesenteric arteriography is the most effective examination (Druy, 1981; Hirsch et al, 1982; Chen et al, 1983); this not only confirms the diagnosis but also defines the anatomical site of bleeding as well as anatomical variations of the arterial blood supply of the liver. Embolisation of the feeding artery is described in the literature (Villasante et al, 1977; Hirsch et al, 1982; Struyven et al, 1982) but this method could not be applied in our case since the site of perforation was located immediately after the origin of the common hepatic artery.

REFERENCES

BISMUTH, H., 1973. Hemobilia. *New England Journal of Medicine*, *288*, 617–619.

CHEN, F., CHOU, F. F., WANG, C. H. & JANG, Y. I., 1983. Hematobilia from ruptured hepatic artery aneurysm. *Archives of Surgery*, *118*, 759–761.

DRUY, E. M., 1981. Hepatic artery-biliary fistula following percutaneous transhepatic biliary drainage. *Radiology*, *141*, 369–370.

HIRSCH, M., AVINOACH, I., KEYNAN, A. & KHODADADI, J., 1982. Angiographic diagnosis and treatment of hemobilia. *Radiology*, *144*, 771–772.

SHERIDAN, J. T., 1956. Hepatic artery aneurysm. *A. M. A. Archives of Surgery*, *72*, 300–310.

STRUYVEN, J., CREMER, M., PIRSON, P., JEANTY, P. & JEANMART, J., 1982. Post-traumatic bilhemia: diagnosis and catheter therapy. *American Journal of Roentgenology*, *138*, 746–747.

THOMPSON, W. P., 1928. Tuberculous aneurysm of the hepatic artery. *Bulletin of the Johns Hopkins Hospital*, *42*, 113.

VILLASANTE, J. M., ALVAREZ-RODRIGUEZ, R. E. & HERNANDEZ-ORTIZ, J., 1977. Management of post-biopsy hemobilia with selective arterial embolization. *American Journal of Roentgenology*, *128*, 668–671.

Book reviews

Neurosonography of the Pre-term Neonate. Ed. by Edward G. Grant, pp. xii + 116, 1986 (Springer Verlag, New York), DM138.
ISBN 3-540-96219-0 (Berlin)
0-387-96219-0 (New York)

There are two unique conditions which affect the premature infant brain. Edward Grant, as the editor of this short textbook, has brought together several authors to describe the appearances, pathophysiology and prognosis of germinal matrix-related haemorrhage and periventricular leukomalacia. They have set out, not only to give a description of the neuroultrasonographic findings but also to explain the prognostic significance as far as it is currently understood. They have succeeded in producing a clear and concise text supplemented by good quality illustrations.

The book is divided into seven chapters. The first serves as an introduction to the technique of ultrasound scanning of the infant brain for those not entirely familiar with the subject. The illustrations are good photographic reproductions of ultrasound scans alongside the corresponding anatomical brain section. With a well written text, this is one of the best formats for explaining the appearances on real-time ultrasound scans.

Radiologists who are experienced in neuroultrasonography will be aware of the pitfalls of misinterpretation of scan appearances, *e.g.* mistaking a prominent choroid plexus for intraventricular haemorrhage. This aspect is extensively covered in the first chapter and in the individual sections on germinal matrix-related haemorrhage and periventricular leukomalacia. This material will be of value to anyone wishing to become proficient at scanning in the neonatal nursery. Another advantage of the book is the basic explanation which is provided of the pathophysiology of these two conditions and discussion of their management and prognosis.

The pathophysiology is in a short chapter on its own. The other aspects are included in the two longer chapters on germinal matrix-related haemorrhage and periventricular leukomalacia. These chapters are particularly well written and the descriptions and accompanying illustrations should lead to a good understanding of the nature and diagnostic value of the ultrasound findings. Recommendations on optimal timing of scans are also made.

The next section is mainly concerned with the long-term outlook for these patients; unfortunately, they cover the experience of only one unit over an understandably short period of time. The statistics would appear to be similar to other series but in a textbook it would perhaps have been better to give a more comprehensive review of the literature.

Ultrasound appears to be the investigation of choice for the pre-term infant brain but there is still a place for other imaging modalities. The final chapter compares the relative values of computed tomography (CT) with ultrasound in these and other related clinical conditions and indicate where CT may give supplementary information.

It is a clear and concise textbook, of value to general and neuroradiologists who wish to learn more about the imaging of this unique and expanding group of patients. The book does not set out to cover all the abnormalities which can affect the infant brain but has limited itself to the complications of prematurity which it has covered admirably.

Unfortunately, for such a small book, the price does seem rather high but the printing and the photographic reproductions are of a high standard. It is to be recommended for use in the special care baby unit by both radiologists and paediatricians.

J. BRITTON

Ultrasound in Perinatology. Ed. by Nabit F. Maklad, pp. 224, 1986 (Churchill Livingstone, New York), £27.50.
ISBN 0-443-08365-7

This is a book of 11 chapters covering most aspects of perinatology from *in utero* measurements and diagnosis of antenatal abnormalities to the postnatal appearances and management of specific problems. It will be of interest to a wide readership from obstetricians, paediatricians and radiologists, to all those involved in perinatal care. As stated in the preface the volume is "an attempt to present an overview and update of the applications of ultrasound in the perinatal period".

As "an overview", the book probably succeeds but unfortunately the chapters are not of sufficient depth, which detracts from the general value and intention of the work. It is multi-author, with contributions mainly from radiologists, perinatologists and obstetricians. Unfortunately, as a result of this different clinical input, the book as a whole does not hold together very well. There are some overlaps; especially noticeable are those in Chapters 1 and 2 which deal with estimation of gestational age in the third trimester, ultrasound fetal measurements and intra-uterine growth retardation.

The book is well written, easily read and covers most subjects in which a perinatologist may be interested, including ante- and postnatal echocardiography, fetal urinary tract abnormalities, neonatal brain imaging and interventional and surgical procedures.

The illustrations are generally white on black. Their quality varies with the type of equipment used, those taken on more up-to-date equipment reproducing well. The labelling and the legends of the illustrations are generally easily understood and well presented. There are no colour illustrations.

At £27.50, the book is not exceptionally expensive but I think that it has a limited value. Although generally up to date, some interesting new developments have not been included, for example the antenatal use of Doppler.

The book probably succeeds in its intention of being a general overview of perinatology; however, I suspect that the chapters are not in sufficient depth and readers maybe better advised to buy individual books on the subjects covered. For the same reason I do not feel it would be of value to libraries.

R. DEBRUYN

1987, *The British Journal of Radiology*, *60*, 1231–1232

DECEMBER 1987

Case of the month

"All's well that ends well"

By J. Bell, M.R.C.P., F.R.C.R., J. Kabala, M.R.C.P. and *M. Horrocks, M.S., F.R.C.S.

Departments of Radiodiagnosis and *Surgery, Bristol Royal Infirmary, Bristol BS2 8HW

(*Received March 1987*)

An 80-year-old man was admitted for repair of a right inguinal hernia. While on the ward, he complained of back pain in the lower thoracic and upper lumbar region, present for around 3 months, with some pain in the right groin. He was found to have reduced pin-prick sensation in the T12 to L2 dermatomes and a numb area on the lateral aspect of the right thigh.

He had a previous history of a thoraco-abdominal repair of a hiatus hernia 2 years earlier. Post-operatively, he had developed an oesophageal leak into the left hemithorax but this had settled with an intercostal drain without further surgery.

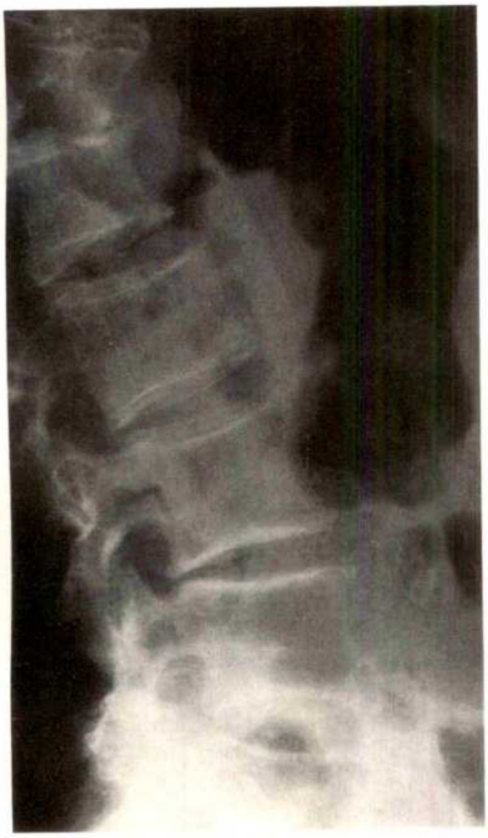


FIG. 1.

Lateral view of lumbar and lower thoracic spine.

Radiographs of his thoraco-lumbar spine (Fig. 1) showed anterior erosions and wedge collapse of the bodies of T12 and L1. The T11–12 and T12–L1 disc spaces were narrowed with sclerotic vertebral end-plates. A chest radiograph showed an old thoracotomy with volume loss and pleural thickening at the left base.

A presumptive diagnosis of spinal metastatic deposits from a bronchogenic carcinoma was made and the patient referred for radiotherapy. At that time, the radiographs were reviewed and it was noted that the appearances were not typical of metastatic deposits and the changes on the chest radiographs were probably all old. In view of the associated disc-space narrowing, an infective lesion was considered although the patient was apyrexial with a normal white blood count. Further radiological advice was therefore sought and a computed tomography (CT) scan (Fig. 2) performed to confirm the diagnosis.

What does the CT scan show, what is your differential diagnosis and how would you proceed?

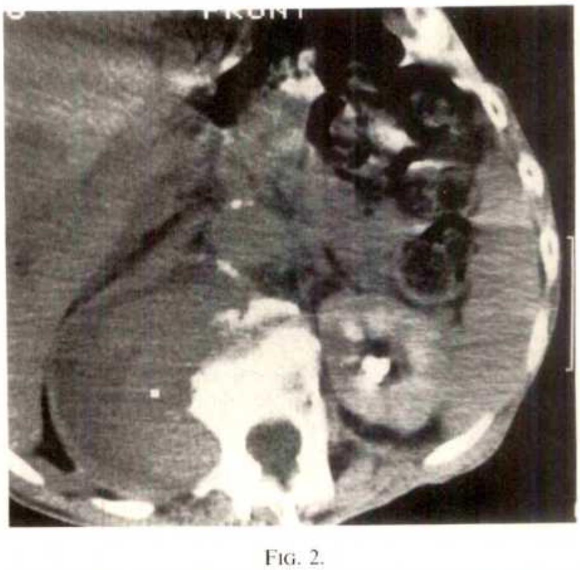


FIG. 2.

CT scan (window 350, centre 44) through upper abdomen at level of L1 (density measurement at site of white square to right of spine = 51).

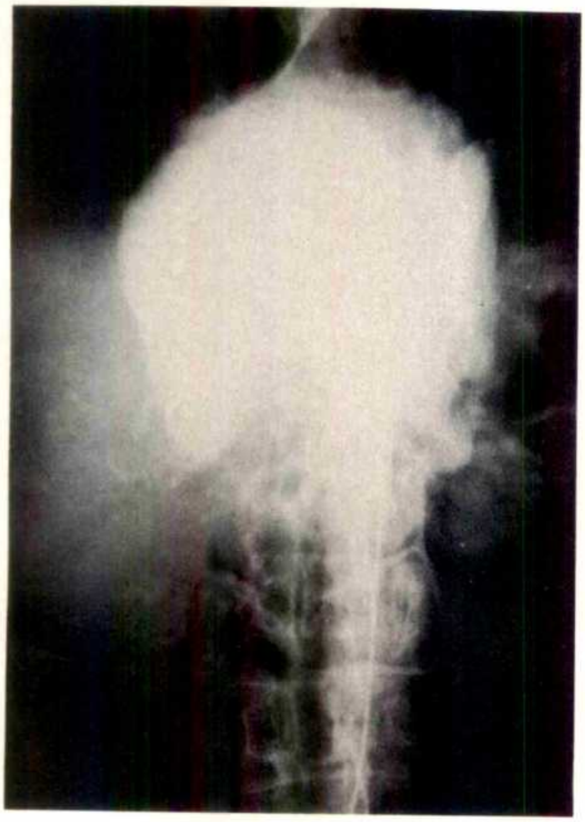


FIG. 3.

Aortogram showing large aneurysm lying anteriorly and mainly to the right of the aorta. Some contrast medium has passed inferiorly and to the right into the lumen of a false aneurysm.

The CT scan shows a large soft-tissue mass of mixed attenuation lying anteriorly and to the right of the upper lumbar vertebral bodies, which are eroded anteriorly. It apparently extends down the right psoas muscle. It was felt that this confirmed the presence of a large psoas abscess and a needle aspiration to identify the responsible organism was done. Only blood was aspirated, the flow being slightly pulsatile. Injection of contrast medium down the biopsy needle showed a large cavity connecting with the aorta. The patient was therefore referred to a vascular surgeon (M.H.). An aortogram (Fig. 3) was performed to confirm the diagnosis of an aneurysm and to demonstrate its full extent. A large aneurysm was shown anterior and to the right of the lower thoracic and upper lumbar vertebral bodies. Some contrast medium was shown passing infero-laterally into the lumen of a false aneurysm. The findings were confirmed at operation when an aortic graft was successfully inserted.

There are many possible causes of anterior erosions of the vertebral bodies. While metastatic deposits are one of the commonest causes, myeloma, lymphoma and extrinsic compression from aneurysms, lymphadenopathy or abscesses can all produce similar appearances.

Paraspinal abscesses may occur with spread of infection, often tuberculous, from adjacent bone or from the disc space. In either instance, both the vertebral bodies and the intervening discs become involved, with narrowing of the disc space and erosion of the vertebral bodies (Epstein, 1976). Although new bone formation may cause some sclerosis, this is usually ill-defined and not limited to the vertebral end-plates as in this case. The latter is more typically associated with degenerative disc disease.

Aortic aneurysms are well known to produce anterior erosion of the vertebral bodies. The bone margins are often well defined and the discs not involved. Such changes can be well shown by CT (Twigg et al, 1975; Godwin et al, 1980). In this case, anterior erosion has been extensive enough to produce some secondary collapse. This appearance, combined with coexistent degenerative changes, produced an initially misleading picture in this patient.

Computed tomography is extremely good for detecting abdominal masses. However it is not always so easy to be sure from where the mass is arising, especially in the case of larger masses (Williams et al, 1984). A dynamic scan with intravenous contrast medium would in this case have clearly demonstrated the nature of the mass but such a technique is only employed when a vascular lesion is suspected before or during scanning. An ultrasound scan of the upper abdomen would probably also have led to the correct diagnosis.

ACKNOWLEDGMENTS

We wish to acknowledge the advice and assistance of Dr W. D. Jeans in the preparation of this case.

REFERENCES

EPSTEIN, B. S., 1976. In *The Spine: a Radiological Text and Atlas*, 4th Edit. (Lea and Febiger, Philadelphia), p. 424.

GODWIN, J. D., HERFKENS, R. L., SKIOLDERBRAND, C. G., FEDERLE, M. P. & LIPTON, M. J., 1980. Evaluation of dissection and aneurysms of the thoracic aorta by conventional and dynamic CT scanning. *Radiology*, *136*, 125–133.

TWIGG, H. L., AXELBAUM, S. P. & SCHELLINGER, D., 1975. Computerised body tomography with the ACTA scanner. *Journal of the American Medical Association*, *234*, 314–317.

WILLIAMS, M. P., SCOTT, I. H. K. & DIXON, A. K., 1984. Computed tomography in 101 patients with a palpable abdominal mass. *Clinical Radiology*, *35*, 293–296.

1987, *The British Journal of Radiology*, *60*, 1233–1235

Short communication

Uptake and additivity of the radiosensitising effects of Ro 03-8799 and SR-2508 in mammalian cells *in vitro*

By M. E. Watts, M. F. Dennis and M. Woodcock

Gray Laboratory of the Cancer Research Campaign, Mount Vernon Hospital, Northwood, Middlesex HA6 2RN

(*Received May 1987 and in revised form August 1987*)

There is currently considerable interest in combining the two 2-nitroimidazole radiosensitisers, Ro 03-8799 and SR-2508. The weak, lipophilic base Ro 03-8799 and the neutral, hydrophilic compound SR-2508 are both efficient radiosensitisers, but the dose-limiting toxic effects of these two agents are clinically somewhat different. The dose-limiting effect for Ro 03-8799 is predominantly central neuropathy (Roberts et al, 1984; Saunders et al, 1984) and that for SR-2508 is predominantly peripheral neuropathy (Coleman et al, 1986). Thus, by combining these two radiosensitisers it should be possible to increase the effective sensitising concentration without increasing toxicity.

The effect of combining these two radiosensitisers should be additive, providing the intracellular distributions of the compounds do not differ greatly. Combinations of two rather similar nitro-containing radiosensitisers have been studied previously (McNally et al, 1978), but the hydrophilic and prototropic characteristics of SR-2508 and Ro 03-8799 differ considerably; hence the subcellular distribution may be different for these two compounds. However, it should be noted that the effect of, for instance, doubling radiosensitiser concentration has a relatively small effect on increasing the sensitiser enhancement ratio (SER). We have studied this additivity of radiosensitisation using clinically relevant concentrations of Ro 03-8799 and SR-2508 and the Chinese hamster cell line V79 379A *in vitro*. Results are presented which demonstrate that the sensitising effects of these two radiosensitisers are additive, and that the cellular uptake of the combined compounds is not significantly different from that for each compound alone.

MATERIALS AND METHODS

Ro 03-8799 (1-(2-nitro-1-imidazolyl)-3-N-piperidino-2-propanol) was supplied by Dr C. E. Smithen of Roche Products Ltd, Welwyn Garden City, Herts, UK and SR-2508 (N-(2-hydroxyethyl)-2-nitro-1H-imidazole-1-acetamide) was donated by the US National Cancer Institute.

Asynchronous logarithmic phase Chinese hamster V79 379A cells were used for all experiments. Cells were X-irradiated at approximately 3 Gy min^{-1} at room temperature in Eagle's MEM + 10% fetal calf serum as described by Adams et al (1976). Cells were incubated under hypoxia in the presence of radiosensitiser for 80 min before irradiation to allow the uptake of drugs to reach plateau levels.

Average intracellular concentrations of radiosensitisers were measured by high-performance liquid chromatography after centrifuging cells through oil as described by Watts et al (1987).

RESULTS

Concentrations in the region of 0.1 mmol dm^{-3} Ro 03-8799 and 1 mmol dm^{-3} SR-2508 are routinely measured in clinical tumours (Saunders et al, 1984; Newman et al, 1986). Using V79 379A cells, values for average intracellular concentrations (C_i/C_e) of 3.28 and 0.42 for Ro 03-8799 and SR-2508 have been measured (Dennis et al, 1985; Watts et al, 1987). Based on these measurements of average intracellular concentrations, extracellular concentrations of 0.03 mmol dm^{-3} Ro 03-8799 and 1 or 2 mmol dm^{-3} SR-2508 were used in the present radiation study.

The SERs for Ro 03-8799 and SR-2508, obtained from full survival curves or measurements made at single radiation doses, are shown as a function of concentration in Fig. 1A. With both compounds, SERs increase with increasing concentration. Figure 1B shows SERs for increasing concentrations of Ro 03-8799 in the presence of 1 or 2 mmol dm^{-3} SR-2508. At concentrations of Ro 03-8799 less than 0.05 mmol dm^{-3}, the level of sensitisation observed is dominated by the presence of SR-2508. Only for concentrations of Ro 03-8799 in excess of 0.05 mmol dm^{-3} does the SER increase with increasing concentration. Also shown in Fig. 1B are the SERs for increasing concentrations of SR-2508 in the presence of 0.03 mmol dm^{-3} Ro 03-8799. At concentrations of SR-2508 less than 0.2 mmol dm^{-3}, the level of sensitisation is dominated by the presence of Ro 03-8799. Full survival curves for each sensitiser alone and in combination, using a range of representative concentrations, showed no effect on the extrapolation number $\bar{n}$ (data not shown).

Average intracellular concentrations (C_i/C_e) of the radiosensitisers plotted as a function of incubation time are shown in Fig. 2. The uptake of SR-2508 alone or in combination with Ro 03-8799 is slow, plateau levels of 0.4 and 0.5 respectively being reached after 100 min. The uptake of Ro 03-8799 alone or in combination with SR-2508 is also time dependent; however, in contrast to SR-2508, it is concentrated within the cells by a factor of 2.9 when alone or by 3.5 in the presence of SR-2508.

DISCUSSION

The uptake data for the individual compounds are within the experimental uncertainties inherent in these types of measurement (Dennis et al, 1985; Watts et al, 1987). The differences in uptake for the combination are not considered to be significantly different to those for each drug alone.

Figures 1A and 1B show clearly that the radiosensitising effects of Ro 03-8799 and SR-2508 are additive. A concentration of 0.03 mmol dm^{-3} Ro 03-8799 alone gives an SER of 1.4 (Fig. 1A); this SER is also given by 0.6 mmol dm^{-3} SR-2508 alone (Fig. 1A). Thus, combining 0.03 mmol dm^{-3} Ro 03-8799 with 2 mmol dm^{-3} SR-2508 (SER 1.75) is equivalent to 2.6 mmol dm^{-3} SR-2508 alone. This concentration should give an SER of 1.85 (from Fig. 1A) if the sensitising efficiencies of the two drugs are additive. Experimentally, SERs of 1.85 and 1.75 were measured.

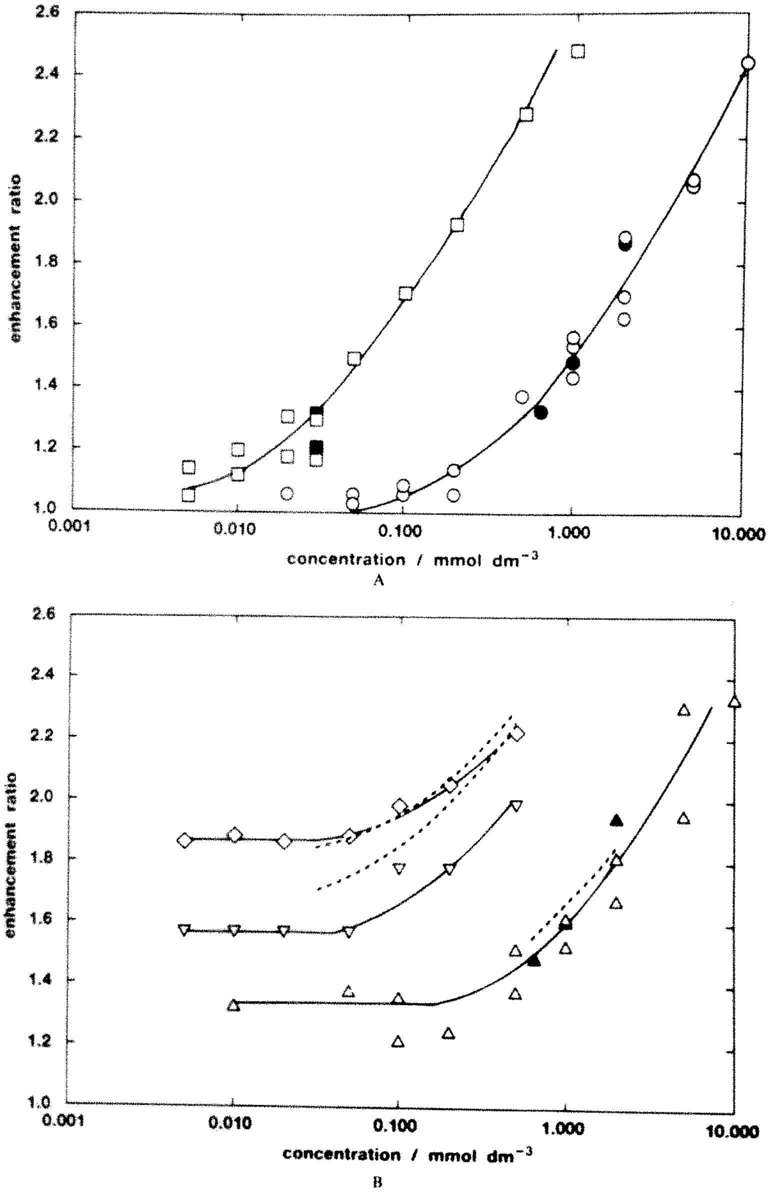


FIG. 1.

SER as a function of sensitiser concentration. (A) □ Ro 03-8799; ○ SR-2508; (B) ◇ 2 mmol dm^{-3} SR-2508; ▽ 1 mmol dm^{-3} SR-2508 both with increasing concentrations of RO 03-8799; △ 0.03 mmol dm^{-3} Ro 03-8799 with increasing concentrations of SR-2508. The solid symbols refer to full survival curves and the open symbols to measurements at a single radiation dose. The dashed lines represent predicted SERs.

Table I shows SERs measured for a range of combinations of Ro 03-8799 and SR-2508 together with the SERs predicted from Fig. 1A. The agreement between predicted and measured SERs strongly indicates that the radiosensitising efficiences of these two drugs are indeed additive. In an earlier study by McNally et al (1978) using the same cell line and combinations of misonidazole and 4-nitroacetophenone (PNAP), the additivity is less obvious due to the concentrations studied; for example, they reported that 5 mmol dm^{-3} misonidazole with or without 0.4 mmol dm^{-3} PNAP gave an SER of 2.4 even though PNAP alone gave an SER of 1.6. This SER of 1.6 was also given by 0.3 mmol dm^{-3} misonidazole, so for this combination the effective concentration of misonidazole was only increased from 5 to 5.3 mmol dm^{-3}. Such a small increase in concentration would result in an undetectable increase in SER. In contrast, combining 0.1 mmol dm^{-3} misonidazole (SER 1.2) with 0.2 mmol dm^{-3} PNAP (SER 1.3) gave an SER of 1.45.

Although Ro 03-8799 and SR-2508 have different modes of neurotoxicity, Stone et al (1986) using a murine *in vivo* tumour system reported an overlap of toxicities. This necessitated a reduction of drug levels when giving the drugs simultaneously, compared with giving them separately. Thus, any benefit from simultaneous administration was lost because of increased toxicity. In contrast, in a clinical study by Newman et al (1986), coadministration of the two drugs was well tolerated. Extrapolating from the average tumour levels measured and the present *in vitro* data, an increase in SER from 1.4 for each drug alone to about 1.55 for coadministration is predicted.

In conclusion, there is experimental evidence that the

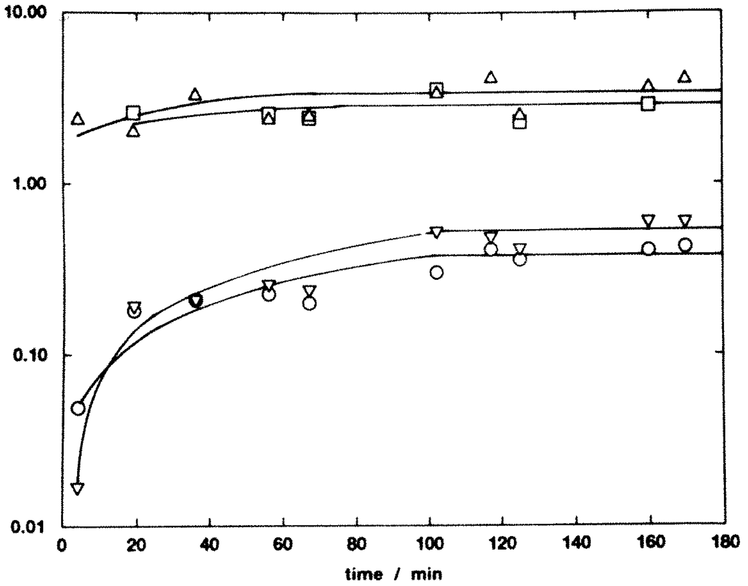


FIG. 2.

Cellular uptake as a function of time. Each point is the mean of triplicate measurements. □ 1 mmol dm^{-3} Ro 03-8799 alone; ○ 1 mmol dm^{-3} SR-2508 alone; △ 1 mmol dm^{-3} Ro 03-8799 measured in the presence of 1 mmol dm^{-3} SR-2508; ▽ 1 mmol dm^{-3} SR-2508 measured in the presence of 1 mmol dm^{-3} Ro 03-8799.

TABLE I

SER MEASURED FOR COMBINATIONS OF Ro 03-8799 AND SR-2508

Ro 03-8799 (mmol dm^{-3})	SR-2508 (mmol dm^{-3})			
	0	0.6	1.0	2.0
0	1.0	1.4	1.55	1.75
0.03	1.4	1.4 (1.55)	1.6, 1.55 (1.7)	1.75, 1.85 (1.85)
0.1	1.7	(1.8)	1.7 (1.85)	1.95 (1.95)
0.5	2.2	(2.25)	2.0 (2.25)	2.2 (2.3)

SERs in parentheses are predicted values, assuming independent action.

radiosensitising effects of Ro 03-8799 and SR-2508 are additive, and there is evidence that the combination of both drugs is clinically tolerated. Thus coadministration of Ro 03-8799 and SR-2508 should result in a modest but beneficial gain in radiosensitisation.

ACKNOWLEDGMENTS

This work is supported by the Cancer Research Campaign. We thank Dr M. R. L. Stratford for measuring the drug levels in the cell samples and Professor J. F. Fowler and Dr P. Wardman for helpful discussion.

REFERENCES

ADAMS, G. E., FLOCKHART, I. R., SMITHEN, C. E., STRATFORD, I. J., WARDMAN, P. & WATTS, M. E., 1976. Electron-affinic sensitization. VII. Correlation between structures, one-electron reduction potentials and efficiences of nitroimidazoles as hypoxic cell radiosensitizers. *Radiation Research, 67,* 9–20.

COLEMAN, C. N., WASSERMAN, T. H., URTASUN, R. C., HALSEY, J., HIRST, V. K., HANCOCK, S. & PHILLIPS, T. L., 1986. Phase I trial of the hypoxic cell radiosensitizer SR-2508: the results of the five to six week drug schedule. *International Journal of Radiation Oncology, Biology, Physics, 12,* 1105–1108.

DENNIS, M. F., STRATFORD, M. R. L., WARDMAN, P. & WATTS, M. E., 1985. Cellular uptake of misonidazole and analogues with acidic or basic functions. *International Journal of Radiation Biology, 47,* 629–643.

MCNALLY, N. J. & DE RONDE, J., 1978. Interaction between electron-affinic sensitizers. *British Journal of Cancer, 37, Suppl. III,* 90–94.

NEWMAN, H. F. V., BLEEHEN, N. M. & WORKMAN, P., 1986. A Phase I study of the combination of two hypoxic cell radiosensitizers, Ro 03-8799 and SR-2508: toxicity and pharmacokinetics. *International Journal of Radiation Oncology, Biology, Physics, 12,* 1113–1116.

ROBERTS, J. T., BLEEHEN, N. M., WORKMAN, P. & WALTON, M. I., 1984. A phase I study of the hypoxic cell radiosensitizer Ro 03-8799. *International Journal of Radiation Oncology, Biology, Physics, 10,* 1755–1758.

SAUNDERS, M. I., ANDERSON, P. J., BENNETT, M. H., DISCHE, S., MINCHINTON, A., STRATFORD, M. R. L. & TOTHILL, M., 1984. The clinical testing of Ro 03-8799—pharmacokinetics, toxicology, tissue and tumor concentrations. *International Journal of Radiation Oncology, Biology, Physics, 10,* 1759–1763.

STONE, H. B., LUU, Y. H. & LAM, K. N., 1986. Sensitization by SR-2508 plus Ro 03-8799. *International Journal of Radiation Oncology, Biology, Physics, 12,* 1097–1100.

WATTS, M. E., DENNIS, M. F., JONES, N. R. & STRATFORD, M. R. L., 1987. A comparison of the intracellular uptake and radiosensitization efficiency in different media of uncharged 2-nitroimidazoles of varying lipophilicity. *International Journal of Radiation Biology,* in press.

1987, *The British Journal of Radiology*, *60*, 1236–1237

Correspondence

(The Editors do not hold themselves responsible for opinions expressed by correspondents)

Barium embolisation during barium enema examination

THE EDITOR—SIR,

I read with interest but some some misgiving the article by Fowlie et al (1987) on barium embolisation during enema examination in colitis. As a cautionary tale it is welcomed, but several observations require further analysis.

Firstly, from the table published by the authors some facts may be deduced. In those patients with no colonic disease, extravasation occurred from the rectum. This implies a local tear due to direct trauma from balloon distension. However, in the diseased colon, the barium leak occurred at the site of disease. Most likely this is due to the increased pressure generated by rectal occlusion, pressures which may exceed 26 kPa (200 mmHg) (Gelfand, 1980) and which cannot be withstood by the bowel wall when it is weakened by active inflammation. These points and their implications for the use of balloon catheters were not brought out in discussion by Fowlie and his colleagues.

A further danger in ulcerative colitis, again borne out by a case in the authors' table is the effect of a catheter balloon in the diseased rectum. The balloon of an 18 Ch. Foley catheter measures 36 mm in diameter when inflated with 30 ml of air. With 50 ml, the diameter is 40 mm. Particularly in an exacerbation of chronic disease, when the rectum may be markedly narrowed, distension by such a mass requires careful consideration.

Thirdly, no mention is made in the paper of preparation for the examination. It is the policy at this hospital, in the even *potentially* active colitic, to start with a plain abdominal radiograph to look for toxic megacolon or perforation. These excluded, the use of chemical or mechanical preparation "is certain to cause discomfort and some aggravation of symptoms" (Bartram, 1983), even if preparation itself is not firmly established as the cause of such complications as the development of toxic megacolon. Hence we study the unprepared colon—"instant enema"—as modified for use in patients with known ulcerative colitis (Thomas, 1979).

The value of this gentle examination in active colitis is well established. To quote Bartram (1983): "The examination causes minimal disturbance to the patient and rarely has there been any suggestion that it has caused any deterioration in the patient's condition. The information it provides is perfectly adequate for the clinician as long as the examination is used within its designated limits". In 17 years to 1983, over 8000 such examinations were performed with no significant complication.

In conclusion, although there are potential dangers in examining patients with acute colitis, these are minimised by the correct use of the instant enema. Bowel preparation and balloon catheters, however, are to be avoided.

Yours, etc.,
M. D. LEWARS

Department of Radiology,
St Bartholomew's Hospital,
West Smithfield,
London EC1A 7BE

(*Received June 1987*)

(*Authors' reply*)

THE EDITOR—SIR,

We agree with Dr Lewars that when extravasation of barium occurs from the rectum local trauma caused by balloon distension is a likely contributory factor, and that this danger is greater where the rectal mucosa is diseased. Likewise we agree that bulb inflators can generate substantial intracolonic pressures. However, we contend that increased intracolonic pressures during a barium enema can occur just as surely with a competent anal sphincter as with a balloon catheter in the rectum. Further, we reject the assertion that balloon catheters are to be avoided. Rather we concur with Gelfand (1980) (whom Dr Lewars quotes) that balloon catheters can be safely employed if certain basic precautions are followed, and we sought to emphasise this in our communication. One of us (G. M. F.) has performed over 10 000 barium enema examinations using a Foley catheter, but taking care not to inflate the balloon excessively, without causing rectal perforation in a single case.

The use of the instant enema without bowel preparation in inflammatory bowel disease was first advocated by Young (1963) but most authors favour some form of bowel preparation (Welin & Brahme, 1961; Simpkins & Stevenson, 1972). Indeed, Bartram (1983) indicates this in his book *Radiology in Inflammatory Bowel Disease* but, regrettably, this is not the impression conveyed by Dr Lewars. In the reported case, bowel preparation was limited to one sachet of Picolax (Nordic Pharmaceuticals) on the day before the examination. We do not think this had any bearing on the subsequent intravasation of barium. In our experience (Fraser & Findlay, 1976) the double-contrast enema, using a colonic activator in the preliminary cleansing enema, carries no greater risk of complications than conventional enema or sigmoidoscopy.

Yours, etc.,
S. FOWLIE
J. R. BARTON
G. M. FRASER

Gastrointestinal Unit and Department of Radiology,
Western General Hospital,
Edinburgh

(*Received June 1987*)

REFERENCES

BARTRAM, C. I., 1983. *Radiology in Inflammatory Bowel Disease*. (Marcel Dekker, New York), p. 6.

FOWLIE, S., BARTON, J. R. & FRASER, G. M., 1987. Barium embolisation during barium enema examination: a report of a case and a review of the literature. *British Journal of Radiology*, *60*, 404–406.

FRASER, G. M. & FINDLAY, J. M., 1976. The double contrast barium enema in ulcerative and Crohn's colitis. *Clinical Radiology*, *27*, 103–112.

SIMPKINS, K. C. & STEVENSON, G. W., 1972. The modified Malmo double contrast barium enema in colitis: an assessment of its accuracy in reflecting sigmoidoscopic findings. *British Journal of Radiology*, *45*, 486–492.

THOMAS, B. M., 1979. The instant enema in inflammatory disease of the colon. *Clinical Radiology*, *30*, 165.

Correspondence

WELIN, S. & BRAHME, F., 1961. The double contrast method in ulcerative colitis. *Acta Radiologica*, *55*, 257–271.

YOUNG, A. C., 1963. The 'instant' barium enema in proctocolitis. *Proceedings of the Royal Society of Medicine*, *56*, 491–494.

Breast screening in China

THE EDITOR—SIR,

On a recent visit to hospital centres in China, shortly after publication of the Forrest Report on Breast Cancer Screening, I was intrigued to find at the Beijing Institute for Cancer Research a number of mobile units for breast X-ray screening, and one for stomach cancer screening.*

The units are contained in large, fully equipped mobile vans which are used to visit factories and towns at some distance from the city centre, and are also used to examine patients visiting the hospital.

An interesting aspect of the breast units is that the Chinese recognise that the patient must not be sent away until an image of diagnostic quality has been obtained; to this end the vans are equipped with a specially developed Xerox-type processing unit (producing black images on ordinary white paper), and are sent out from base staffed with both technicians and a radiologist trained to read the radiographs. The records and findings are immediately fed into a computer installed in the van. At the hospital the vans are connected to the hospital electricity supply, but when sent out are capable of generating their own power.

It is conjectural whether three or four mobile units alone could screen the entire population of Beijing and its environs, but it is interesting that the Chinese people are aware that something positive must be done about cancer control (cancer is a very common condition in China, and cancer or tumour hospitals abound). Possibly the most important lesson to be learned, however, is that if mobile breast screening is to be introduced on a national basis in Britain, the films must be processed immediately, before the patient is sent away, so that recalls do not have to be made because of inadequate radiographic quality. To do otherwise in this highly emotive examination is not only cruel; it is immoral.

Yours, etc.,
A. E. HUGH

Department of Radiology,
North Staffordshire Royal Infirmary,
Princes Road,
Stoke-on-Trent ST4 7LN
(*Received June 1987*)

Translumbar aortography

THE EDITOR—SIR,

I was interested to see the papers from Jeans et al (1986a, b) and the letter from Carmichael (1987). In my opinion (Ludwig, 1986; Gmelin & Arlart, 1987) the advent of intravenous digital subtraction angiography (DSA) has made it unnecessary to do either translumbar aortograms or aortography from the arm. Both investigations have an appreciable complication rate. Patients needing these investigations are rarely seen as emergencies, and if the writers do not have the appropriate equipment to do DSA the patients should be transferred to a more up-to-date department.

Yours, etc.,
H.-J. MAURER

Chefartz Radiobiol. Abt.,
St Josefs Krankenhaus,
Landhausstrasse 25,
6900 Heidelberg 1,
West Germany
(*Received April 1987*)

---

*Further details may be obtained from Dr Liu Jinzhou, Department of Radiology, Beijing Institute for Cancer Research, Beijing, China.

TABLE I

COMPARISON OF ADVANTAGES AND DISADVANTAGES OF DIFFERENT METHODS OF OBTAINING IMAGES

Technique	Advantages	Disadvantages
DSA (in general)	Reduced film costs Immediate images Quicker procedures	Major capital cost Smaller images Reduced spatial resolution
Intravenous DSA	Outpatient investigation Quick procedure Rapid throughput Less risk to patient	Movement artefacts Reduced spatial resolution Large volumes of contrast medium
Intra-arterial DSA	Reduced movement artefacts Increased contrast resolution Reduced volume of contrast medium	Risks of arterial catheters Moderate spatial resolution Often inpatient procedure
Conventional radiography	Good spatial resolution Shows relation of artery to surrounding area	Reduced contrast resolution Slow visualisation High film costs
Manual subtraction	Good spatial and contrast resolution	Labour intensive Slow visualisation High film costs

(Author's reply)

THE EDITOR—SIR,

I agree with Professor Maurer that in patients without femoral pulses, intravenous DSA is useful in showing the lower aorta, iliac vessels and femoral bifurcation. However, few patients have no femoral pulses. In our practice, the need for angiography in symptomatic patients is based on the finding in the vascular laboratory of a fall in ankle pressure on exercise, and some 30% of our patients having aortography will then proceed to Gruntzig dilatation, usually as part of the same procedure (McLean et al, 1987). In my opinion, intravenous DSA as the initial procedure in that situation is unnecessary and runs the risk of causing an overload of contrast medium. I would agree that intra-arterial DSA is useful to demonstrate an area of the leg shown incompletely at aortography.

Digital subtraction angiography is a helpful technique in some situations, but seems to me to have been oversold. I append a list of its advantages and disadvantages (Table I).

Yours, etc.,
W. D. JEANS

Department of Radiology,
The Bristol Royal Infirmary,
Bristol BS2 8HW

(Received April 1987)

REFERENCES

CARMICHAEL, J. H. E., 1987. Translumbar aortography (letter to the editor). *British Journal of Radiology*, *60*, 304.

GMELIN, E. & ARLART, I. P., 1987. *Digitale Subtraktionsangiographie*.

JEANS, W. D., DANTON, R. M., BAIRD, R. N. & HORROCKS, M., 1986a. A comparison of the costs of vascular surgery and balloon dilatation in lower limb ischaemic disease. *British Journal of Radiology*, *59*, 453–456.

——1986b. The effects of introducing balloon dilatation into vascular surgery practice. *British Journal of Radiology*, *59*, 457–459.

LUDWIG, J. W. V., 1986. *Digital Subtraction Angiography* (Philips Medical Systems, Eindhoven).

MCLEAN, L., JEANS, W. D., HORROCKS, M. & BAIRD, R. N., 1987. The place of percutaneous transluminal angioplasty in the treatment of patients having angiography for ischaemic disease of the lower limb. *Clinical Radiology*, *38*, 157–160.

Modification of the Selectron standard applicator for gynaecological treatments

THE EDITOR—SIR,

The Selectron standard gynaecological applicator is a modified Fletcher–Suit applicator. It consists of one intrauterine and two ovoid tubes. It is very important, especially if high-activity sources are used, that both intrauterine and ovoid tubes stay in constant positions during the treatment. We have found that the intrauterine tube of this applicator was rather difficult to hold at a constant angle in the uterus. This was due to a construction flaw in the adjustable fixing mechanism (Nucletron Est. Part No. 006.008). It was impossible to tighten Rings A and B (Fig. 1) firmly enough to prevent movement of the intrauterine tube. The result was that the tube could pivot in the sagittal plane in spite of a large quantity of a gauze packing being used. This could cause quite a big change in the dose distribution during the treatment.

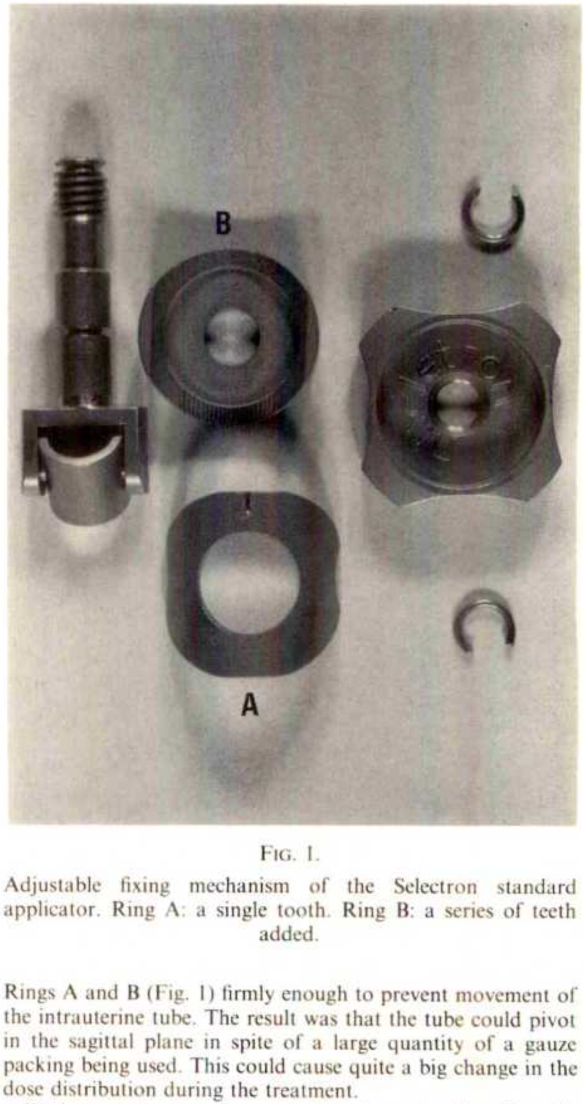


FIG. 1.

Adjustable fixing mechanism of the Selectron standard applicator. Ring A: a single tooth. Ring B: a series of teeth added.

We have made a small construction change in the adjustable fixing mechanism which prevents any rotation of the intrauterine tube during treatment. On Ring A a single tooth and on Ring B a series of teeth have been made. We recommend this modification since it can easily be made by a skilful machinist and markedly improves the performance of this Selectron applicator.

Yours, etc.,
J. CYGLER
B. LAVIGNE
G. P. RAAPHORST

Department of Medical Physics, OCTRF,
Ottawa Clinic, Civic Division,
190 Melrose Avenue,
Ottawa, Ontario K1Y 4K7

(Received June 1987 and in revised form July 1987)

1987, *The British Journal of Radiology*, *60*, 1239–1240

A quarter of a century ago

This is the first in a series of occasional articles on the history of radiology, as reflected in the *Journal*.

Twenty-five years ago, if you asked a trainee what he wanted to be when he grew up, as likely as not he would say a vascular radiologist. That was the time when a young radiologist worth his salt was busy catheterising the aorta and, if he was very good, trying his hand at selective renal and mesenteric injections.

The chat at radiological meetings had a distinctive agricultural ring, with talk of pigtails and shepherd's crooks. Symptomatic of that age was a paper in this *Journal* by young Louis Kreel and Roger Pyle, neither of whom apparently had their Fellowship, on vascular impressions on the renal collecting system; Eric Samuel described a technique for catheterising the aorta via the brachial artery and John Dow was telling us how to deliver a large quantity of contrast medium into the heart when investigating shunts. Much interest was also being shown in the photographic technique of image subtraction as described by Ziedses des Plantes.

Few of us at that time could have anticipated the imaging revolution which was about to illuminate the diagnostic scene. Most radiology at that time was simply an extension of "what our fathers had done", and the great authorities and experts at the time were the senior men. Names like Campbell Golding, Rohan Williams, Kemp Harper and James Bull were the men in charge, to whom we all looked for a lead.

Today the situation is different; the advent of digitisation and computers in CT scanning and MRI, as well as the advance in ultrasonography, have meant that many of today's old men, unable or unwilling to come to terms with new techniques and concepts, have been left behind and the heroes of today's trainees are the younger technocrats, driving the new machines.

In this context it is interesting to look back at the contributions and the contributors to the *BJR* of 25 years ago. It is perhaps surprising that that well known disease, so beloved of today's examiners, the medullary sponge kidney, was receiving only its second case report in British radiology, following the initial one of Dr E. L. "Billy" Rubin and his Liverpool colleagues in the then Faculty Journal of 1959. Campbell Golding's Mackenzie Davidson Lecture "The Shoulder: the Forgotten Joint" is as relevant today as it was at that time, and those of us who were privileged to hear that lecture have never forgotton the insight he gave into that complicated joint. His theme of "failure to recognise the significance of shadows or even to see them at all" is an everyday experience of the radiologist and it is perhaps surprising to remember that, although calcification in joint cartilage had been recognised 20 years earlier, the condition of chondrocalcinosis and the associated syndrome of pseudogout was not recognised until 1962. Again, what would examiners today do without that condition?

In 1962 we were searching for safer contrast agents and were still in the age of retroperitoneal air insufflation and gas myelography; Frimann Dahl headed an article on gastric parietography in which the stomach and peritoneal cavity were filled with gas in order to assess abnormalities of the gastric wall. Jim Murray from Limerick described a clinical trial of Biloptin and the 3 h cholecystogram with Solu-Biloptin was assessed.

It was also the year of red faces for those who thought that the opacification of the intravertebral discs in Egyptian mummies was the result of widespread alkaptonuria in the Ptolemaic period; much more significant were the first case reports in the British Radiological literature of thalidomide deformities by Ronald Grainger, Alun Morris and Peter Ward, from Sheffield.

In June 1962 the *Journal* published the proceedings of a meeting in Cambridge, on veterinary radiology—this event prompted an editorial in which it was stated that "an Institute meeting outside London is itself an innovation"! That situation is hard to believe today, when it is the exception for a large meeting to be held in London.

Computed tomography is now so much a part of neuroradiology that we must remember that, even 25 years ago, neuroradiology was not only an advanced science, but also an art requiring great practical skills. Direct carotid and vertebral puncture and air encephalography were everyday procedures and those of us who were involved remember the interest evoked by Manny Schecter's article in the July *BJR* on autotomography of midline intracranial structures on air encephalography. This technique, which was an extension of yet another original ideal of Ziedses des Plantes, was developed by Dr Schecter at Queen Square, demonstrated in Stockholm and subsequently taken to New York, where the article was written. The importance of the technique was again acknowledged by an editorial, yet who of today's trainees has ever even seen an air encephalogram?

J. T. PATTON

There is nothing new under the sun, they say, and reading the *British Journal of Radiology* for the year 1962 certainly confirms this saying. 1987 has been the year of AIDS and of Chernobyl. The latter has once again emphasised public concern about the hazards of radiation. In reading the non-diagnostic papers published in the *Journal* in 1962, one is struck by the large number of contributions concerned with radiation protection. In the introduction to a symposium on the radiological hazards to patients at the Annual Congress, Sir Brian Windeyer concluded that "... the time must soon come when radiation hazards should be placed in proper perspective. It might even be legitimate to think of the unrestrained use of tobacco as a greater danger to the community". It is doubtful if, 25 years later, we have yet placed radiation in "proper perspective", at least in the eye of the general public.

Today AIDS is the great medical issue of the day. In 1962 the *Journal* published one paper on the treatment of the AIDS-related tumour, Kaposi's sarcoma. Lionel Cohen presented a study of time, dose and volume effects in the treatment of "this extraordinarily frequent disease in Africa" and concluded that a substantial proportion of patients could be cured by radiotherapy provided that the disease was not widely disseminated.

Supervoltage therapy was still new 25 years ago. Fletcher made a strong case for its use in the treatment of carcinoma of the cervix and there was much discussion about the necessity for rotational therapy using high-energy machines. Rotation therapy had been introduced for 250 kV X rays. The main conclusion of a symposium on this subject was that, while beams should be rotatable, fixed beams and wedge filters were probably going to be the standard, with rotation therapy only used in special circumstances. This conclusion is certainly borne out by modern practice.

The importance of the new high-energy machines was further emphasised by a symposium at the Annual Congress on developments in linear accelerators, 8 years after the first two 4 MeV machines were installed in Newcastle and Manchester. The possibility of going from the standard 4 MeV to the, then, exceptionally high energy of 40 MeV, was mentioned and the relative merits of X-band (3 cm wavelength) and S-band (10 cm wavelength) accelerators were under discussion.

In 1987 it is still not clear as to what the role of neutron beams will be in radiotherapy. In 1962 some of the first results from the pre-therapeutic experiments with neutrons from the MRC cyclotron at Hammersmith were being reported. From his pioneering studies on pig skin, Fowler was able to explain the serious long term skin damage that Stone had reported, and was able to indicate how this problem might be overcome. This, of course, was a major factor in convincing clinicians that neutrons were worth a second try.

Radiosensitisers hardly featured in 1962. However, in a short letter Bridges concluded that "The widespread use of sensitising agents in radiotherapy is still a pipe dream, but we should not underestimate their potential value". I wonder what we would say today!

In 1962 radiobiologists were still coming to terms with cell-survival curves and trying to understand the meaning of the survival-curve parameters (do we understand them now?). Alper and colleagues defined, for the first time, the quasi-threshold dose, D_q, now part of our everyday jargon. Hall demonstrated, probably for the first time, how split-dose experiments can give estimates of the survival-curve parameters when the full curve cannot easily be determined. Twenty-five years later his approach is the basis for many fractionation studies to extract survival-curve parameters for a wide range of dose-limiting normal tissues, and hence to predict the outcome of different fractionation regimes, a topic much in vogue today.

N. J. McNALLY

The British Journal of Radiology

FOUNDED 1896

The Editorial Committee consists of:

The Editors:

J. T. PATTON, F.R.C.P., F.R.C.R. N. J. MCNALLY, B.SC., M.SC., PH.D.

The Deputy Editors:

C. K. BOMFORD, B.SC., M.PHIL., F.INST.P. D. G. SHAW, F.R.C.P., F.R.C.R.

and

The Associate Editors:

J. E. ADAMS, M.B., B.S., M.R.C.P., F.R.C.R.
P. R. BLAKE, M.B., B.S., B.SC., F.R.C.R.
J. A. BULLIMORE, M.B., B.S., M.R.C.S., L.R.C.P., D.M.R.T., F.R.C.R.
P. DAWSON, B.SC., PH.D., M.B., B.S., M.R.C.P., M.INST.P., F.R.C.R.
R. DICK, M.B., B.S., M.R.A.C.R., F.R.C.R.
S. DISCHE, M.D., F.R.C.R.
F. A. DUCK, PH.D., M.I.E.E.E.
A. H. FREEMAN, M.B., B.S., F.R.C.R.
R. M. HARRISON, B.SC., M.SC., PH.D., M.INST.P.
J. W. HOPEWELL, B.SC., PH.D.
W. D. JEANS, M.B., B.S., F.R.C.R.
C. H. JONES, B.SC., PH.D., F.INST.P.
B. KENDALL, F.R.C.P., F.R.C.R., D.M.R.D.
D. M. KING, M.B., B.S., F.R.C.R., D.M.R.D.
H. W. C. LOOSE, D.M.R.D., F.R.C.R.
H. B. MEIRE, M.B., B.S., L.R.C.P., M.R.C.S., D.M.R.D., D.OBST. R.C.O.G., F.R.C.R.
D. W. PILLING, M.B., CH.B., D.C.H., D.M.R.D., F.R.C.R.
M. J. RAPHAEL, M.A., M.D., F.R.C.P., F.R.C.R., D.M.R.D.
J. R. K. SAVAGE, D.SC.
R. A. SHIELDS, PH.D.
A. R. VALENTINE, M.B., B.S., M.R.C.S., L.R.C.P., F.R.C.R., D.M.R.D.
G. H. WHITEHOUSE, M.B., B.S., F.R.C.P., F.R.C.R., D.M.R.D.
A. G. WILSON, M.B., M.R.C.P., F.R.C.R.
E. P. WRAIGHT, M.B., B.CHIR., PH.D., D.M.R.T.

The Associate Editors Overseas are:

P. ARMSTRONG, M.B., B.S., F.R.C.R., D.M.R.D. (North America)
H. K. BADDELEY, M.B., B.S., D.M.R.D., F.R.C.R., M.R.A.C.R. (Australasia)
S. G. A. CHENERY, PH.D., F.C.C.P.M. (North America)
B. J. CREMIN, F.R.C.R., F.R.A.C.R. (South Africa)
R. FOX, D.PHIL. (Australia)
M. TAKAHASHI, M.D. (Japan)
D. M. TAYLOR, D.SC., C.CHEM., F.R.S.C. (Continental Europe)

Managing Editor: LYNN WHITFIELD, B.SC.

© The British Institute of Radiology, 1987

New Series

VOLUME 60

JANUARY TO DECEMBER, 1987

Published by
THE BRITISH INSTITUTE OF RADIOLOGY
36 Portland Place, London W1N 4AT

INDEX TO AUTHORS—continued

Goodfellow, T., Hyde, I., Burge, D. M., Freeman, N. V., 993
Gozzi, G. *See* Padovani, R.
Grabenwöger, F. *See* Dock, W.
Graif, M., Itzchak, Y., Strauss, S., Dolev, E., Mohr, R., Wolfstein, I., 439
Grant, A. M., Kehoe, T. M., Law, J., 1019
Gravelle, I. H. *See* Flook, D.
Gray, J. M. *See* Blake, G. M.
Gray, R. *See* Doran, R. M. L.
Gray, R. R., St Louis, E. L., Grosman, H., 1067
Greenhalgh, R. M. *See* McIvor, J.
Gregor, A. *See* O'Donoghue, J. A.
Gregory, W. M. *See* Richards, M. A.
Griffin, J. F. *See* Foster, C. J.
Griffiths, T. M. *See* Fitzgerald, E. J.
Grosman, H. *See* Gray, R. R.
Guggiana, P. *See* Mourad, K.
Guillou, P. J. *See* Ubhi, C. S.
Gupta, R. K., Chawla, R., Pant, C. S., 411
Gupta, S. C. *See* Rothwell, C. I.
Gwilt, D. J. *See* Mahendran, M.

Haddad, M. C. *See* Saksouk, F. A.
Hadley, D. M., 940
Hadley, D. M. *See* Condon, B. R.
Hainau, B. *See* Sehested, M.
Halimi, P. H. *See* Doyon, D.
Hall, E. J. *See* Marchese, M. J.
Hall-Craggs, M. A. *See* Lee, S. H.
Hamilton-Wood, C., 199, 940
Hammond, S. M. *See* White, D. R.
Hanka, R. *See* Barton, E.
Hannan, J. *See* Brydon, W. G.
Harding, L. K., 915
Harman, J. *See* Flook, D.
Harnett, A. N., Hungerford, J. L., Lambert, G. D.,Hirst, A., Darlison, R., Hart, B. L., Trodd, T. C., Plowman, P. N., 753
Harnett, A. N. *See* Plowman, P. N.
Harper, J. S. *See* Thompson, S. A.
Hart, B. L. *See* Harnett, A. N.
Hartnell, G. G., Kiely, E. A., Williams, G., Gibson, R. N., 1063
Hawass, N. *See* Kolawole, T.
Hawkes, D. J., Jackson, D. F., 726
Hayward, S. J., McIvor, J., Burdge, A. H., Jewkes, R. F., Williams, G., 79
Haywood, J. M. *See* Cowen, A. R.
Hegedus, L. *See* Karstrup, S.
Hemingway, A. P. *See* Phillips, G. W. L.
Henderson, R. G., Rahmatulla, T. D., 511
Hendry, J. H. *See* Moore, J. V.
Henson, J., McCall, I. W., O'Brien, J. P., 69
Henson, P. *See* Fox, R.
Herskovitz, P. I. *See* Avrahami, E.
Heystraten, F. M. J. *See* Barentsz, J. O.
Hickey, D. S. *See* Jenkins, J. P. R.
Hickey, D. S. *See* Prendergast, D. J.
Hicks, P. *See* Lea Thomas, M.
Higson, G. R., 1049
Hill, D. *See* Ritchie, D. A.
Hill, S. J. *See* Rowley, K. A.
Hilton-Jones, D. *See* Oberhaensli, R. D.
Hinchliffe, M. *See* McNally, N. J.
Hira, N. *See* Steger, A. C.
Hirst, A. *See* Doughty, D.
Hirst, A. *See* Harnett, A. N.
Hobbs, J. R. *See* Starer, F.
Hoeffel, J. C., Capron, F., Jung, J. F., Bernard, C., 288
Hoeffel, J. C., Didier, F., Chantereau, D., Medoc, J. M., Muller, J. P., 707
Holdaway, I. M. *See* Dodd, G. W.
Holm, H. H. *See* Karstrup, S.
Holt, J. A. G., 100
Hopewell, J. W., Morris, A. D., Dixon-Brown, A., 1099
Hopewell, J. W. *See* Calvo, W.
Horniblow, P. J., 782
Horrocks, M. *See* Bell, J.
Howard, D. J. *See* Lloyd, G. A. S.
Huang, T.-Y., Yam, L. T., Li, C.-Y., 765
Huang, C. Y. *See* Lau, S. P. C.
Hudson, F. R., 205
Hugh, A. E., 1237
Hungerford, J. L. *See* Harnett, A. N.
Hunter, R. D. *See* Jones, D. A.
Hunter, R. D. *See* Lukka, H. R.
Husband, J. E. *See* Bellamy, E. A.
Huvos, A. G. *See* Rossleigh, M. A.
Hyde, I. *See* Goodfellow, T.

Ibbertson, H. K. *See* Dodd, G. W.
Irving, H. C. *See* Ubhi, C. S.
Isherwood, I. *See* Foster, C. J.
Isherwood, I. *See* Jenkins, J. P. R.
Isherwood, I. *See* Johnson, R. J.
Isherwood, I. *See* Prendergast, D. J.
Itai, Y. *See* Yamauchi, T.
Itzchak, Y. *See* Graif, M.

Jackson, D. F. *See* Hawkes, D. J.
Jackson, J. E., Thomas, A. M. K., 721
Jackson, P. C., Stevens, P. H., Smith, J. H., Kear, D., Key, H., Wells, P. N. T., 375
Jackson, P. C. *See* Key, H.
Jacolot, A. *See* Doyon, D.
Jago, J. R., Gibson, C. J., Diffey, B. L., 127
James, R. D. *See* Johnson, R. J.
Jeans, S. P., 495
Jeans, W. D., 1238
Jeans, W. D. *See* Key, H.
Jeffree, M. A., Nolan, D. J., 402
Jenkins, A. *See* Condon, B. R.
Jenkins, J. P. R., Braganza, J. M., Hickey, D. S., Isherwood, I., Machin, M., 333
Jenkins, J. P. R., Hickey, D. S., Isherwood, I., 1041
Jenkins, J. P. R. *See* Johnson, R. J.
Jenkins, J. P. R. *See* Prendergast, D. J.
Jennings, C. M., Collins, M. C., 508
Jewell, S. E. *See* Richards, M. A.
Jewkes, R. F. *See* Hayward, S. J.
Jha, A. N. *See* Butler, P.
Johnson, G., Ormerod, I. E. C., Barnes, D., Tofts, P. S., MacManus, D., 143, 1041
Johnson, R. J., Jenkins, J. P. R., Isherwood, I., James, R. D., Schofield, P. F., 761
Johnson, R. J. *See* Bradey, N.
Joiner, M. C. *See* Carl, U. M.
Jones, D. A., Notley, H. M., Hunter, R. D., 481
Jones, S. *See* Conry, B. G.
Jung, J. F. *See* Hoeffel, J. C.
Juul, N. *See* Sehested, M.

Kabala, J. E., Wilde, P., 981
Kabala, J. *See* Bell, J.
Kamoi, I. *See* Kawamura, N.
Kanoh, M. *See* Araki, Y.
Kaprio, J., Alanko, A., Kivisaari, L., Standertskjöld-Nordenstam, C.-G., 459

INDEX TO VOLUME 60

Kardamakis, D., Berry, R. J., 297
Karstrup, S., Holm, H. H., Torp-Pedersen, S., Hegedüs, L., 667
Kauppila, A., Sipilä, P., Koivula, A., 1093
Kawai, R. *See* Araki, Y.
Kawamura, N., Kamoi, I., Shigyo, R., 1031
Kear, D. *See* Jackson, P. C.
Keeling, F. P., Lea Thomas, M., 235
Keeton, B. R. *See* Rubin, C. M. E.
Kehoe, T. M. *See* Grant, A. M.
Kendall, B. E. *See* Stevens, J. M.
Kenney, I. J., Wild, S. R., 865
Key, H., Jackson, P. C., Thomas, E. A., Jeans, W. D., Davies, E. R., 1083
Key, H. *See* Jackson, P. C.
Khan, F. *See* Kolawole, T.
Kiely, E. A. *See* Hartnell, G. G.
King, R. H. *See* Barton, E.
Kingston, J. E. *See* Doniach, I.
Kirkpatrick, A. E., Law, J., 73, 418
Kivisaari, L. *See* Kaprio, J.
Klepetko, W. *See* Dock, W.
Klipstein, R. H., Firmin, D. N., Underwood, S. R., Nayler, G. L., Rees, R. S. O., Longmore, D. B., 105
Kobayashi, H., Zusho, H., 209
Koga, T. *See* Tomooka, Y.
Koivula, A. *See* Kauppila, A.
Kolawole, T., Banna, M., Hawass, N., Khan, F., Rahman, N., 702
Kozlowski, K., Scougall, J., 705
Krüger, K.-G. *See* Wernecke, K.
Kuroiwa, T. *See* Tomooka, Y.

Lam, K. S. *See* Lam, W. C.
Lam, W. C., Partowmah, M., Lee, D. J., Wharam, M. D., Lam, K. S., 361
Lambert, G. D. *See* Doughty, D.
Lambert, G. D. *See* Harnett, A. N.
Lau, S. P. C., Chan, F. L., Yu, Y. L., Woo, E., Huang, C. Y., 347
Laufer, G. *See* Dock, W.
Lavelle, J. *See* Cosgriff, P. S.
Lavigne, B. *See* Cygler, J.
Law, B. *See* Willson, S. A.
Law, J., 179, 231
Law, J. *See* Grant, A. M.
Law, J. *See* Kirkpatrick, A. E.
Lawson, R. S. *See* Bevis, C. R. A.
Lawson, R. S. *See* Wujanto, R.
Lazarus, C. *See* Clarke, S. E. M.
Lea Thomas, M., Hicks, P., 123
Lea Thomas, M. *See* Keeling, F. P.
Leach, M. O. *See* Ott, R. J.
Lee, D. J. *See* Lam, W. C.
Lee, S. H., Hall-Craggs, M. A., Lees, W. R., 1030
Lees, W. R. *See* Shorvon, P. J.
Lees, W. R. *See* Lee, S. H.
Legg, N. J. *See* Brooks, D. J.
Leinster, S. J., Whitehouse, G. H., 457
Leopold, G. R. *See* Willson, S. A.
Leslie, M. P. *See* Williams, D. S.
Letienne, G. *See* Gaux, J. C.
Lewars, M. D., 1236
Li, C.-Y. *See* Huang, T.-Y.
Lindsell, D. R. M. *See* Mendelson, R. M.
Lintott, D. *See* Bulgim, O.
Lloyd, G. A. S., Lund, V. J., Phelps, P. D., Howard, D. J., 957
Lodge, J. P. A., Brennan, T. G., Chapman, A. H., 710
Longmore, D. B. *See* Klipstein, R. H.
López, I. *See* Pulpeiro, J. R.
Lopez-Ibor, L. *See* Doyon, D.
Lorino, C. O., Finn, M., 193
Loupas, T., McDicken, W. N., Allan, P. L., 389
Love, H. G. *See* Foster, C. J.
Lukka, H. R., Moore, C. J., Hunter, R. D., 355
Lund, V. J. *See* Lloyd, G. A. S.
Lushbaugh, C. C., Fry, S. A., Ricks, R. C., 1159
Lye, R. H. *See* Butler, P.
Lyon, M. F., 16
Lyons, K., Evans, C., 93

Machin, M. *See* Jenkins, J. P. R.
MacManus, D. *See* Johnson, G.
Maeda, Y. *See* Araki, Y.
Mahendran, M., Fitzgerald-Finch, O. P., Gwilt, D. J., 595
Maisey, M. N. *See* Clarke, S. E. M.
Malisan, M. R. *See* Padovani, R.
Malpas, J. S. *See* Doniach, I.
Manning, A. *See* Bulgim, O.
Marchese, M. J., Zaider, M., Hall, E. J., 573
Marks, A. M. *See* Doughty, D.
Marsden, P. K. *See* Ott, R. J.
Martin, D. F. *See* Carrington, B. M.
Matthews, C. *See* Absy, M.
Matthews, I. P. *See* Rogers, K. D.
Maurer, H.-J., 1237
McCabe, R. *See* Binstock, P.
McCall, I. W. *See* Colhoun, E. N.
McCall, I. W. *See* Henson, J.
McCready, V. R. *See* Ott, R. J.
McCready, V. R. *See* Webb, S.
McDicken, W. N. *See* Loupas, T.
McEwan, A. J. *See* Blake, G. M.
McHugo, J. M., McKeown, C., Brown, M. T., Weller, P., Shah, K. J., 137
McIvor, J., Steiner, T. J., Perkin, G. D., Greenhalgh, R. M., Rose, F. C., 117
McIvor, J. *See* Hayward, S. J.
McKeown, C. *See* McHugo, J. M.
McKnight, L. *See* Colhoun, E. N.
McNally, N. J., de Ronde, J., Minchinton, A. I., Hinchliffe, M., 96
McNally, N. J. *See* Carl, U. M.
McNally, N. J. *See* Patton, J. T.
Medoc, J. M. *See* Hoeffel, J. C.
Meller, S. *See* Webb, S.
Melonas, C. F. *See* Beyers, J. A.
Mendelson, R. M., Lindsell, D. R. M., 414
Merrick, M. V. *See* Brydon, W. G.
Merrick, M. V. *See* Gerrard, M.
Merrick, M. V. *See* Nimmo, M. J.
Messios, N. *See* Walmsley, D.
Messmer, J. *See* Cho, S.-R.
Metreweli, C. *See* Absy, M.
Michell, M. *See* Powell-Jackson, P.
Minasian, H. *See* Mourad, K.
Minchinton, A. I. *See* McNally, N. J.
Mistry, R. *See* Clarke, S. E. M.
Mitchell, M. E. *See* Cory, D. A.
Mitchell, R. A. *See* Constant, O.
Mitomo, M. *See* Araki, Y.
Miyazaki, S. *See* Tomooka, Y.
Mohr, R. *See* Graif, M.
Mole, R. H., 17, 939
Monro, P. *See* Belli, A. M.
Moore, C. J. *See* Lukka, H. R.
Moore, J. V., West, C. M. L., Hendry, J. H., 303
Moores, B. M. *See* Booler, R. V.

INDEX TO AUTHORS
1987

Absy, M., Metreweli, C., Matthews, C., Al Khader, A., 525
Ackery, D. M. *See* Blake, G. M.
Al Khader, A. *See* Absy, M.
Alanko, A. *See* Kaprio J.
Aldridge, S. M., Birchall, I. W. L., 195
Allan, P. L. *See* Loupas, T.
Allan, P. L. *See* Nimmo, M. J.
Allen, M. J. *See* Annis, J. A. D.
Alpert, M., Brody, S., 190
Anderson, P. *See* Chandler, S. T.
Anderson, P. *See* Vaughan, A. T. M.
Andretta, M. *See* Rubaltelli, L.
Angel, C. Y. *See* Gaux, J. C.
Annis, J. A. D., Finlay, D. B. L., Allen, M. J., Barnes, M. R., 1059
Araki, Y., Mori, S., Kanoh, M., Maeda, Y., Kawai, R., Mitomo, M., 395
Asbury, D. L. *See* Booler, R. V.
Aves, B., 725
Avrahami, E., Herskovitz, P. I., Cohn, D. F., 701
Axon, A. *See* Bulgim, O.

Baker, M. K. *See* Cory, D. A.
Banerjee, A. K., 728
Banna, M. *See* Kolawole, T.
Bannon, R. P. *See* Dixon, A. K.
Barbina, V. *See* Padovani, R.
Bardach, G. *See* Dock, W.
Barentsz, J. O., Ruijs, J. H. J., Heystraten, F. M. J., Buskens, F., 499
Barnes, D. *See* Johnson, G.
Barnes, M. R. *See* Annis, J. A. D.
Barnett, C. *See* Binstock, P.
Barrett, N. K. *See* Treweeke, P.
Barter, S. *See* Stevens, J. M.
Barton, E., Gallagher, S., Flower, C. D. R., Hanka, R., King, R. H., Sherwood, T., 893
Barton, J. R. *See* Fowlie, S.
Bartram, C. I. *See* Conry, B.G.
Bateman, J. E. *See* Ott, R. J.
Batty, V. *See* Ott, R. J.
Bauer, M., Schulz-Wendtland, R., Fritz, P., von Fournier, D., 477
Bayliss, A. P., Deans, H., 100
Beaver, P. F., 38
Bell, J., Kabala, J., Horrocks, M., 1231
Bellamy, E. A., Nicholas, D., Husband, J.E., 1205
Belli, A. M., Dow, C. J., Monro, P., 1026
Bernard, C. *See* Hoeffel, J. C.
Berry, R. J., 947
Berry, R. J. *See* Kardamakis, D.
Best, J. J. K. *See* Turnbull, L. W.
Bevis, C. R. A., Shields, R. A., Lawson, R. S., Testa, H. J., 661
Beyers, J. A., Melonas, C. F., 877
Bijvoet, O. L. M. *See* Papapoulos, S. E.
Binstock, P., Barnett, C., McCabe, R., 714
Birchall, I. W. J., Bird, G. L. A., Rutherfoord, G. S., 293
Birchall, I. W. J. *See* Aldridge, S. M.
Bird, G. L. A. *See* Birchall, I. W. J.
Blake, G. M., Gray, J. M., Zivanovic, M. A., McEwan, A. J., Fleming, J. S., Ackery, D. M., 685
Blake, G. M., Zivanovic, M. A., McEwan, A. J., Condon, B. R., Ackery, D. M., 253
Bolia, A. *See* Naik, D. R.
Bomford, C. K. *See* Walton, L.
Booler, R. V., Moores, B. M., Dovas, T., Asbury, D. L., 515
Boon, A. W. *See* Naik, D. R.
Boothroyd, A. E., Russell, J. G. B., 203
Bore, P. J. *See* Oberhaensli, R. D.
Bourdillon, P.J., 1171
Bowring, C. S., Tobin, A. N., Chudley, C., Vennart, W., 101
Bowyer, F. M. *See* Whyte, A. M.
Bradey, N., Johnson, R. J., Read, G., 487
Bradley, D. A., Chong, C. S., 175
Bradwell, A. R. *See* Vaughan, A. T. M.
Braganza, J. M. *See* Jenkins, J. P. R.
Brennan, T. G. *See* Lodge, J. P. A.
Brennen, S. E. *See* Clarkson, D. McG.
Brenot, Ph. *See* Gaux, J. C.
Brock, A. P. *See* Smith, E.
Brody, S. *See* Alpert, M.
Brooks, D. J., Carr, D. H., Legg, N. J., 295
Brown, A. P., Fixsen, J. A., Plowman, P. N., 261
Brown, M. T. *See* McHugo, J. M.
Brownlee, W. C. *See* Foster, C. J.
Bruce, J. *See* Elliot, S.
Brydon, W. G., Merrick, M. V., Hannan, J., 563
Buchan, R. C. T., 728
Bulgim, O., Manning, A., Lintott, D., Axon, A., 543
Bullimore, J. A. *See* Tomlinson, M. J.
Bundrick, T. *See* Cho, S.-R.
Burdge, A. H. *See* Hayward, S. J.
Burge, D. M. *See* Goodfellow, T.
Burwell, R. G. *See* Upadhyay, S. S.
Buskens, F. *See* Barentsz, J. O.
Butler, P., Freer, C. E. L., Jha, A. N., Lye, R. H., 323

Cabellon Jr, S. *See* Moreno, A. J.
Calkins, A. R., Stehman, F. B., Wass, J. L., Smirz, L. R., Ellis, J. H., 975
Calvert, M. H. *See* Ritchie, D. A.
Calvo, W., Hopewell, J. W., Reinhold, H. S., van den Berg, A. P., Yeung, T. K., 1109
Candiani, F. *See* Rubaltelli, L.
Capron, F. *See* Hoeffel, J. C.
Carl, U. M., McNally, N. J., Joiner, M. C., 583, 937
Carmichael, J. H. E., 304
Carmichael, J. H. E. *See* Russell, J. G B.
Carr, D. H. *See* Brooks, D. J.
Carrington, B. M., Martin, D. F., 997
Cassar-Pullicino, V. *See* Colhoun, E. N.
Chan, F. L. *See* Lau, S. P. C.
Chandler, S. T., Anderson, P., 881
Chantereau, D. *See* Hoeffel, J. C.
Chapman, A. H. *See* Lodge, J. P. A.
Chapman, C. E. *See* Vaughan, A. T. M.
Charny, M. C., Roberts, G. M., Roberts, C. J., 553
Chawla, R. *See* Gupta, R. K.
Chennells, P. N. *See* Fowler, R. C.
Cherryman, G. R. *See* Williams, M. P.
Cho, S.-R., Messmer, J., Bundrick, T., Turner, M. A., 547
Chong, C. S. *See* Bradley, D. A.
Chudley, C. *See* Bowring, C. S.
Clack, R. *See* Ott, R. J.
Clarke, O. F. *See* Cowen, A. R.
Clarke, R. H., 1182
Clarke, S. E. M., Lazarus, C., Mistry, R., Maisey, M. N., 1089

INDEX TO VOLUME 60

Clarkson, D. McG., Brennen, S. E., 1119
Clifton, A. G., Ginsberg, L., Webb, W. J. S., Valentine, A. R., 1023
Cohen, M. D., Scales, R. L., Eigen, H., Scott, P., Tepper, R., Cory, D. A., Smith, J. A., 223
Cohn, D. F. *See* Avrahami, E.
Colhoun, E. N., Cassar-Pullicino, V., McCall, I. W., Davie, M. W. J., 925
Colhoun, E. N., Fitzgerald, E. J., McKnight, L., 645
Collins, M. C. *See* Jennings, C. M.
Condon, B. R., Patterson, J., Wyper, D., Jenkins, A., Hadley, D. M., 83
Condon, B. R. *See* Blake, G. M.
Conry, B. G., Jones, S., Bartram, C. I., 1215
Constant, O., Mitchell, R. A., 1139
Contento, G. *See* Padovani, R.
Coral, A. P., 601
Cory, D. A., Tarver, R. D., Baker, M. K., Wass, J. L., Rink, R. C., Mitchell, M. E., 449
Cory, D. A. *See* Cohen, M. D.
Cosgriff, P. S., Lavelle, J., 717
Cotton, P. B. *See* Shorvon, P. J.
Coulden, R. A. R., Dixon, A. K., 518
Cowen, A. R., Haywood, J. M., Workman, A., Clarke, O. F., 1001
Cowen, A. R., Workman, A., Haywood, J. M., Clarke, O. F., 1011
Cox, R. A. F., 1180
Crone, M., Watt, I., 1035
Curran, J. G., Ryan, M. J., 929
Cygler, J., Lavigne, B., Raaphorst, G. P., 1238

Dahniya, M. H., 113
Dale, R. G., 300
Daly, B. *See* Towers, M. J.
Darlison, R. *See* Harnett, A. N.
Davie, M. W. J. *See* Colhoun, E. N.
Davies, E. R. *See* Key, H.
Dawson, P., 728
Dawson, P., Penhaligon, M., Smith, E., Saunders, J., 201
Dawson, P. *See* Trewhella, M.
de Ronde, J. *See* McNally, N.J.
Deans, H. *See* Bayliss, A. P.
DeMaria, J. E. *See* Richards, D. G.
Dennis, M. F. *See* Watts, M. E.
Derin, H., Yetkin, E., Özkilic, H., Özekli, K., Yaman, C., 873
Dewit, L., Oussoren, Y., 1037
Didier, F. *See* Hoeffel, J. C.
Diffey, B. L. *See* Jago, J. R.
Dixon, A. K., Bannon R. P., 215
Dixon, A. K. *See* Coulden, R. A. R.
Dixon, P. M., Fletcher, E. W. L., 923
Dixon-Brown, A. *See* Hopewell, J. W.
Dock, W., Grabenwöger, F., Bardach, G., Pinterits, F., Klepetko, W., Laufer, G., 1228
Dodd, G. W., Ibbertson, H. K., Fraser, T. R. C., Holdaway, I. M., Wattie, D., 849
Dolev, E. *See* Graif, M.
Doniach, I., Kingston, J. E., Plowman, P. N., Malpas, J. S., 1223
Doran, R. M. L., Gray, R., Virjee, J. P., 417
Doughty, D., Lambert G. D., Hirst, A., Marks, A. M., Plowman, P. N., 269
Dovas, T. *See* Booler, R. V.
Dow, C. J. *See* Belli, A. M.
Downing, R. *See* Rowley, S.
Doyon, D., Ducot, B., Halimi, P. H., Spira, A., Noviant, Y., Jacolot, A., Lopez-Ibor, L., 671
Ducot, B. *See* Doyon, D.
Dykes, P. W. *See* Vaughan, A. T. M.

Eden, O. B. *See* Gerrard, M.
Edgren, M., Révész, L., 723
Edmondson, B., 1174
Eigen, H. *See* Cohen, M. D.
Ekberg, O., 637
Elliot, S., Bruce, J., 1132
Ellis, F., 51
Ellis, J. H. *See* Calkins, A. R.
Evans, C. *See* Lyons, K.
Ewing, R. *See* Fowler, R. C.

Fabretto, M. *See* Padovani, R.
Finlay, D. B. L. *See* Annis, J. A. D.
Finn, M. *See* Lorino, C. O.
Firmin, D. N. *See* Klipstein, R. H.
Fitzgerald, E. J., Griffiths, T. M., 593
Fitzgerald, E. J. *See* Colhoun, E. N.
Fitzgerald, P., O'Connell, D., 505
Fitzgerald-Finch, O. P. *See* Mahendran, M.
Fixsen, J. A. *See* Brown, A. P.
Fleming, J. S. *See* Blake, G. M.
Fletcher, E. W. L. *See* Dixon, P. M.
Flook, D., Gilhome, R. W., Harman, J.,Gravelle, I. H., Webster, D. J. T., 455
Flower, C. D. R. *See* Barton, E.
Flower, M. A. *See* Webb, S.
Forbes, A. *See* Powell-Jackson, P.
Forbes, W. St C. *See* Rothwell, C. I.
Forsling, M. *See* Trewhella, M.
Foster, C. J., Brownlee, W. C., Griffin, J. F., Yates, J., Love, H. G., Isherwood, I., 969
Foster, C. J., Sekiya, T., Love, H. G., Brownlee, W. C., Griffin, J. F., Isherwood, I., 327
Fowler, J. F., 777
Fowler, R. C., Chennells, P. M., Ewing, R., 649
Fowlie, S., Barton, J. R., Fraser, G. M., 404, 1236
Fox, N. E., Twentyman, P. R., 381
Fox, R., Henson, P., 726
Fraser, G. M. *See* Fowlie, S.
Fraser, T. R. C. *See* Dodd, G. W.
Fredericks, P. *See* Moreno, A. J.
Freedman, L. S., 1071
Freeman, N. V. *See* Goodfellow, T.
Freer, C. E. L. *See* Butler, P.
Fritz, P. *See* Bauer, M.
Frost, R. A. *See* Shorvon, P. J.
Fry, F. A., 1147
Fry, S. A. *See* Lushbaugh, C. C.
Fuentos, J. *See* Plowman, P. N.
Fullarton, G. M. *See* Ritchie, D. A.
Furui, S. *See* Yamauchi, T.

Gale, A. G., Roebuck, E. J., Riley, P., Worthington, B. S., 887
Gallagher, S. *See* Barton, E.
Galloway, G. J. *See* Oberhaensli, R. D.
Garcia-Hidalgo, E. *See* Pulpeiro, J. R.
Gaux, J. C., Vuthien, H., Letienne, G., Angel, C. Y., Pernes, J. M., Raynaud, A., Brenot, Ph., 693
Gerrard, M., Eden, O. B., Merrick, M. V., 393
Gibson, C. J. *See* Jago, J. R.
Gibson, R. N. *See* Hartnell, G. G.
Giles, G. R. *See* Ubhi, C. S.
Gilhome R. W. *See* Flook, D.
Ginai, A. Z., 343
Ginsberg, L. *See* Clifton, A. G.

INDEX TO AUTHORS—continued

Moores, B. M. *See* Rowley, K. A.
Morcos, S. K., Thomas, D. G., 780
Moreno, A. J., Fredericks, P., Pan, P., Perez, R. G., Cabellon Jr, S., 91
Mori, S. *See* Araki, Y.
Moriarty, M. J. *See* Seymour, C. B.
Morris, A. D. *See* Hopewell, J. W.
Mothersill, C. *See* Seymour, C. B.
Moulton, A. *See* Upadhyay, S. S.
Mourad, K., Guggiana, P., Minasian, H., 287
Muller, J. P. *See* Hoeffel, J. C.
Mustafa, A. A., Vasisht, C. M., Sumanasekara, S. J., 513

Nadezhina, N. M., 1169
Naik, D. R., Bolia, A., Boon, A. W., 506
Nayler, G. L. *See* Klipstein, R. H.
Nénot, J. C., 1163
Nias, A. H. W. *See* Smith, E.
Nicholas, D. *See* Bellamy, E. A.
Nicholson, A. A., Young, W. T., 725
Nimmo, M. J., Merrick, M. V., Allan, P. L., 861
Nisbet, A. P., 589
Nobbs, D. J., 418
Nolan, D. J. *See* Jeffree, M. A.
Notley, H. M. *See* Jones, D. A.
Noviant, Y. *See* Doyon, D.

O'Brien, J. P. *See* Henson, J.
O'Connell, D. *See* Fitzgerald, P.
O'Donoghue, J. A., Wheldon, T. E., Gregor, A., 279
O'Malley, B. P. *See* Walmsley, D.
O'Neil, T. *See* Upadhyay, S. S.
Oberhaensli, R. D., Galloway, G. J., Hilton-Jones, D., Bore, P. J., Styles, P., Rajagopalan, B., Taylor, D. J., Radda, G. K., 367
Ogilvie, B. C. *See* Rubin, C. M. E.
Ohtomo, K. *See* Yamauchi, T.
Ormerod, I. E. C. *See* Johnson, G.
Orton, C. G., 300
Ott, R. J., Batty, V., Webb, S., Flower, M. A., Leach, M. O., Clack, R., Marsden, P. K., McCready, V. R., Bateman, J. E., Sharman, H., Smith, A., 245
Ott, R. J. *See* Webb, S.
Oussoren, Y. *See* Dewit, L.
Özekli, K. *See* Derin, H.
Özkilic, H. *See* Derin, H.

Padovani, R., Contento, G., Fabretto, M., Malisan, M. R., Barbina, V., Gozzi, G., 155
Pai, G. R., Reed, N. S., Ruddell, W. S. J., 1125
Pan, P. *See* Moreno, A. J.
Pant, C. S. *See* Gupta, R. K.
Papapoulos, S. E., Steendijk, R., Bijvoet, O. L. M., 285
Parker, C. *See* Williams, E. D.
Partowmah, M. *See* Lam, W. C.
Patterson, J. *See* Condon, B. R.
Patton, J. T., McNally, N. J., 1239
Payne, N. I., Whitehouse, G. H., 535
Penhaligon, M. *See* Dawson, P.
Perez, R. G. *See* Moreno, A. J.
Perkin, G. D. *See* McIvor, J.
Pernes, J. M. *See* Gaux, J. C.
Peters, P. E. *See* Wernecke, K.
Phelps, P. D. *See* Lloyd, G. A. S.
Phillips, G. W. L., Hemingway, A. P., 188
Pinterits, F. *See* Dock, W.
Pittarello, F. *See* Rubaltelli, L.
Plowman, P. N., Fuentos, J., Harnett, A. N., 931
Plowman, P. N. *See* Brown, A. P.
Plowman, P. N. *See* Doniach, I.
Plowman, P. N. *See* Doughty, D.
Plowman, P. N. *See* Harnett, A. N.
Pochin, E. E., 42
Powell-Jackson, P., Forbes, A., Michell, M., Williams, R., 1221
Praisontarangkul, O.-A. *See* Singcharoen, T.
Prendergast, D. J., Hickey, D. S., Jenkins, J. P. R., Isherwood, I., 1142
Prescott, M. C. *See* Wujanto, R.
Priest, N. D., 677
Princenthal, R. A. *See* Willson, S. A.
Pulpeiro, J. R., López, I., Soleto, T., Ruiz, J. C., Garcia-Hidalgo, E., 1128

Raaphorst, G. P. *See* Cygler, J.
Radda, G. K. *See* Oberhaensli, R. D.
Rahman, N. *See* Kolawole, T.
Rahmatulla, T. D. *See* Henderson, R. G.
Rajagopalan, B. *See* Oberhaensli, R. D.
Ramsden, D. *See* Walton, L.
Rankin, D. *See* Williams, E. D.
Raynaud, A. *See* Gaux, J. C.
Read, G. *See* Bradey, N.
Reed, N. S. *See* Pai, G. R.
Rees, R. S. O. *See* Klipstein, R. H.
Reinhold, H. S. *See* Calvo, W.
Révész, L. *See* Edgren, M.
Reznek, R. H. *See* Richards, M. A.
Richards, D. G., Stafford, A. J., DeMaria, J. E., 775
Richards, M. A., Gregory, W. M., Webb, J. A. W., Jewell, S. E., Reznek, R. H., 241
Rickards, D. *See* Trewhella, M.
Ricks, R. C. *See* Lushbaugh, C. C.
Ridgway, J. P., Turnbull, L. W., Smith, M. A., 423
Ridgway, J. P. *See* Turnbull, L. W.
Riley, P. *See* Gale, A. G.
Rink, R. C. *See* Cory, D. A.
Ritchie, D. A., Hill, D., Fullarton, G. M., Calvert, M. H., 502
Roberts, C. J. *See* Charny, M. C.
Roberts, C. J. *See* Rogers, K. D.
Roberts, G. M. *See* Charny, M. C.
Roebuck, E. J. *See* Gale, A. G.
Rogers, K. D., Matthews, I. P., Roberts C. J., 463
Rose, F. C. *See* McIvor, J.
Rosenthal, F. D. *See* Walmsley, D.
Rossleigh, M. A., Smith, J., Yeh, S. D. J., Huvos, A. G., 497
Rothwell, C. I., Forbes, W. St C., Gupta, S. C., 1197
Rowley, K. A., Hill, S. J., Watkins, R. A., Moores, B. M., 167
Rowley, S., Downing, R., 773
Roy, R. R. *See* Williams, E. D.
Rubaltelli, L., Sponga, T., Candiani, F., Pittarello, F., Andretta, M., 1211
Rubin, C. M. E., Ogilvie, B. C., Keeton, B. R., 133
Ruddell, W. S. J. *See* Pai, G. R.
Ruijs, J. H. J. *See* Barentsz, J. O.
Ruiz, J. C. *See* Pulpeiro, J. R.
Russell, J. G. B., Carmichael, J. H. E., 781
Russell, J. G. B., Webb, G. A. M., 681
Russell, J. G. B. *See* Boothroyd, A. E.
Rutherfoord, G. S. *See* Birchall, I. W. J.
Ryan, M. J. *See* Curran, J. G.

INDEX TO VOLUME 60

Saksouk, F. A., Haddad, M. C., 1135
Samuel, E., 987
Sargent, J. D. *See* Starer, F.
Saunders, J. *See* Dawson, P.
Savit, R. M., 713
Scales, R. L. *See* Cohen, M. D.
Schofield, P. F. *See* Johnson, R. J.
Schulz-Wendtland, R. *See* Bauer, M.
Scott, O. C. A., 1042
Scott, O. C. A. *See* Smith, E.
Scott, P. *See* Cohen M. D.
Scougall, J. *See* Kozlowski, K.
Sehested, M., Juul, N., Hainau, B., Torp-Pedersen, S., 351
Sekiya, T. *See* Foster, C. J.
Seymour, C. B., Mothersill, C., Moriarty, M. J., Tipton, K. F., 577
Shah, K. J. *See* McHugo, J. M.
Sharma, H. *See* Ott, R. J.
Sheppard, P. W., White, F. E., 1028
Sherwood, T. *See* Barton, E.
Shields, R. A. *See* Bevis, C. R. A.
Shields, R. A. *See* Wujanto, R.
Shigyo, R. *See* Kawamura, N.
Shimoda, Y. *See* Tomooka, Y.
Shorvon, P. J., Lees, W. R., Frost, R. A., Cotton, P. B., 429
Singcharoen, T., Praisontarangkul, O.-A., 1137
Sipilä, P. *See* Kauppila, A.
Skaane, P., Skjennald, A., Solberg, L. A., 407
Skjennald, A. *See* Skaane, P.
Smirz, L. R. *See* Calkins, A. R.
Smith, A. *See* Ott, R. J.
Smith, E., Scott, O. C. A., Nias, A. H. W., Brock, A. P., 601
Smith, E. *See* Dawson, P.
Smith, J. *See* Rossleigh, M. A.
Smith, J. A. *See* Cohen, M. D.
Smith, J. H. *See* Jackson, P. C.
Smith, M. A. *See* Ridgway, J. P.
Smith, M. A. *See* Turnbull, L. W.
Smith, O., 181
Solberg, L. A. *See* Skaane, P.
Soleto, T. *See* Pulpeiro, J. R.
Spira, A. *See* Doyon, D.
Sponga, T. *See* Rubaltelli, L.
St Louis, E. L. *See* Gray, R. R.
Stafford, A. J. *See* Richards, D. G.
Standertskjöld-Nordenstam, C.-G. *See* Kaprio, J.
Starer, F., Sargent, J. D., Hobbs, J. R., 1189
Steendijk, R. *See* Papapoulos, S. E.
Steger, A. C., Whitecross, S. E. S., Hira, N., 1141
Stehman, F. B. *See* Calkins, A. R.
Steiner, T. J. *See* McIvor, J.
Stevens, J. M., Barter, S., Kendall, B. E., 185
Stevens, P. H. *See* Jackson, P. C.
Strauss, S. *See* Graif, M.
Styles, P. *See* Oberhaensli, R. D.
Sumanasekara, S. J. *See* Mustafa, A. A.

Tarver, R. D. *See* Cory, D. A.
Taylor, D. J. *See* Oberhaensli, R. D.
Tepper, R. *See* Cohen, M. D.
Terano, A. *See* Yamauchi, T.
Testa, H. J. *See* Bevis, C. R. A.
Testa, H. J. *See* Wujanto, R.
Thomas, A. M. K. *See* Jackson, J. E.
Thomas, D. G. *See* Morcos, S. K.
Thomas, E. A. *See* Key, H.
Thomlinson, R. H., 735
Thompson, S. A., Harper, J. S., 597
Thorne, M. C., 32
Tipton, K. F. *See* Seymour, C. B.
Tobin, A. N. *See* Bowring, C. S.
Tofts, P. S. *See* Johnson, G.
Tomlinson, M. J., Bullimore, J. A., 89
Tomooka, Y., Koga, T., Shimoda, Y., Kuroiwa, T., Miyazaki, S., Torisu, M., 290
Torisu, M. *See* Tomooka, Y.
Torp-Pedersen, S. *See* Karstrup, S.
Torp-Pedersen, S. *See* Sehested, M.
Towers, M. J., Daly, B., 493
Travis, R. C., 933
Treweeke, P., Barrett, N. K., 417
Trewhella, M., Forsling, M., Rickards, D., Dawson, P., 445
Trodd, T. C. *See* Harnett, A. N.
Turnbull, L. W., Ridgway, J. P., Smith, M. A., Best, J. J. K., 517
Turnbull, L. W. *See* Ridgway, J. P.
Turner, M. A. *See* Cho, S.-R.
Twentyman, P. R. *See* Fox, N. E.

Ubhi, C. S., Irving, H. C., Guillou, P. J., Giles, G. R., 599
Underwood, S. R. *See* Klipstein, R. H.
Upadhyay, S. S., O'Neil, T., Burwell, R. G., Moulton, A., 519
Upton, A. C., 1

Valentine, A. R. *See* Clifton, A. G.
van den Berg, A. P. *See* Calvo, W.
Vanker, E. A., 1126
Vasisht, C. M. *See* Mustafa, A. A.
Vaughan, A. T. M., Anderson, P., Dykes, P. W., Chapman, C. E., Bradwell, A. R., 567
Vennart, W. *See* Bowring, C. S.
Virjee, J. P. *See* Doran, R. M. L.
von Fournier, D. *See* Bauer, M.
Vuthien, H. *See* Gaux, J. C.

Walmsley, D., Messios, N., O'Malley, B. P., Rosenthal, F. D., 935
Walton, L., Bomford, C. K., Ramsden, D., 897
Wass, J. L. *See* Calkins, A. R.
Wass, J. L. *See* Cory, D. A.
Watkins, R. A. *See* Rowley, K. A.
Watt, I. *See* Crone, M.
Wattie, D. *See* Dodd, G. W.
Watts, M. E., Dennis, M. F., Woodcock, M., 1233
Webb, G. A. M. *See* Russell, J. G. B.
Webb, J. A. W. *See* Richards, M. A.
Webb, S., Ott, R. J., Flower, M. A., McCready, V. R., Meller, S., 557
Webb, S. *See* Ott, R. J.
Webb, W. J. S. *See* Clifton, A. G.
Webster, D. J. T. *See* Flook, D.
Weller, P. *See* McHugo, J. M.
Wells, P. N. T. *See* Jackson, P. C.
Wernecke, K., Peters, P. E., Kruger, K.-G., 655
West, C. M. L. *See* Moore, J. V.
Wharam, M. D. *See* Lam, W. C.
Wheldon, T. E. *See* O'Donoghue, J. A.
White, D. R., Woodard, H. Q., Hammond, S. M., 907
White, F. E. *See* Sheppard, P. W.
Whitecross, S. E. S. *See* Steger, A. C.
Whitehouse, G. H. *See* Leinster, S. J.
Whitehouse, G. H. *See* Payne, N. I.
Whyte, A. M., Bowyer, F. M., 400
Wild, S. R., 100
Wild, S. R. *See* Kenney, I. J.

INDEX TO AUTHORS—continued

Wilde, P. *See* Kabala, J. E.
Wilkinson, J. M., 919
Williams, D. S., Leslie, M. D., 1226
Williams, E. D., Parker, C., Rankin, D., Roy, R. R., 780
Williams, G. *See* Hartnell, G. G.
Williams, G. *See* Hayward, S. J.
Williams, M. P., Cherryman, G. R., 1131
Williams, M. V., 469
Williams, R. *See* Powell-Jackson, P.
Willson, S. A., Princenthal, R. A., Law, B., Leopold, G. R., 771
Witcombe, J. B., 937
Wolfstein, I. *See* Graif, M.
Woo, E. *See* Lau, S. P. C.
Woodard, H. Q. *See* White, D. R.
Woodcock, M. *See* Watts, M. E.
Workman, A. *See* Cowen, A. R.
Worthington, B. S. *See* Gale, A. G.
Wright, J. K., 1177
Wujanto, R., Lawson, R. S., Prescott, M. C., Testa, H. J., 869
Wujanto, R., Testa, H. J., Shields, R. A., 780
Wyper, D. *See* Condon, B. R.

Yam, L. T. *See* Huang, T.-Y.
Yaman, C. *See* Derin, H.
Yamauchi, T., Itai, Y., Furui, S., Ohtomo, K., Terano, A., 531
Yates, J. *See* Foster, C. J.
Yeh, S. D. J. *See* Rossleigh, M. A.
Yetkin, E. *See* Derin, H.
Yeung, T. K. *See* Calvo, W.
Yoong, P. M. F., 1021
Young, W. T. *See* Nicholson, A. A.
Yu, Y. L. *See* Lau, S. P. C.

Zaider, M. *See* Marchese, M. J.
Zivanovic, M. A. *See* Blake, G. M.
Zusho, H. *See* Kobayashi, H.

SUBJECT INDEX
1987

List of sections:
- Radiodiagnosis
  - Bones and joints (excluding skull)
  - Neuroradiology (including skull)
  - Cardiovascular system
  - Respiratory tract
  - Digestive tract
  - Liver and biliary tract, spleen, pancreas
  - Urinary tract
  - Haemopoietic, lymphatic, reticulo-endothelial system
  - Reproductive system
  - Endocrine system
  - Ear, nose, throat, mouth, eyes
  - Breast and soft tissues
  - Paediatrics
  - Contrast media and other drugs
  - Apparatus and technical aspects
  - Organisation and statistics
  - Computed tomography (head)
  - Computed tomography (whole body)
  - Computed tomography (apparatus and technical aspects)
  - Interventional radiology
- Ultrasound
  - Clinical aspects
  - Apparatus and technical aspects
- Nuclear medicine
  - Clinical aspects
  - Apparatus and technical aspects
- Nuclear magnetic resonance
- Physics
  - Applied to radiodiagnosis
  - Applied to radiotherapy
  - Applied to nuclear medicine
- Radiotherapy
  - Results and clinical aspects
  - Apparatus and technical aspects
- Cancer chemotherapy
- Radiobiology
  - Applied to radiotherapy
  - Effects of radiation quality
  - Fractionation studies
  - Hyperthermia and irradiation
  - Sensitisers and protectors
  - Other studies
- Hyperthermia
- Hazards and radiation protection
- Lectures and addresses
- Education
- Proceedings
- Obituaries
- Awards
- Book reviews

RADIODIAGNOSIS

Bones and Joints

(excluding skull)

Disc damage above a spondylolisthesis, 69
Paget's disease of bone in Africans, 113
Massive intracranial pannus and a pseudomeningocoele in the atlanto-dental interval in rheumatoid arthritis (Case report), 185
Measurements of internal auditory meatus by polytomography. I. Normal subjects, 209
Computed tomography of the post-operative lumbar spine: the need for, and optimal dose of, intravenous contrast medium, 215
A tumour-like bone lesion as a manifestation of vitamin D-resistant hypophosphataemic osteomalacia (Case report), 285
Dysplasia epiphysealis hemimelica of the ulna (Case report), 288
Congenital hemicerebral arterial ectasia complicating unilateral megalencephaly (Case report), 395
A photopenic lesion in osteosarcoma (Case report), 497
Ultrasound diagnosis of profunda femoris pseudo-aneurysm following nail-plate fixation of a transcervical femoral fracture (Case report), 502
Avoidance of ring artefacts in lumbar spine computed tomography in obese patients (Correspondence), 518
A new method using ultrasound for measuring femoral anteversion (torsion): technique and reliability, 519
Interventional radiology of the spine, October 16, 1986 (BIR Proceedings), 603
Neuropathic arthropathy as a complication of post-traumatic syringomyelia (Case report), 702
Congenital bilateral glenoid hypoplasia: a report of four cases (Case report), 705
Metaphyseal dyschondroplasia with cone-shaped epiphyses (Case report), 707
Radiological features of systemic mast-cell disease, 765
Paget's disease of bone in Africans (Correspondence), 782
Radiological assessment of Paget's disease of bone after treatment with the biphosphonates EHDP and APD, 849
Unusual disco-vertebral changes in Gaucher's disease (Case report), 925
A review of cervical-spine radiographs in casualty patients, 1059
An unusual inguinal swelling (Case of the month), 1139
Regression of the radiological changes of Gaucher's disease following bone marrow transplantation, 1189
Computed tomographic myelography in the investigation of childhood scoliosis and spinal dysraphism, 1197

Neuroradiology

(including skull)

Neurological morbidity of arch and carotid arteriography in cerebrovascular disease. The influence of contrast medium and radiologist, 117
Massive intracranial pannus and a pseudomeningocoele in the atlanto-dental interval in rheumatoid arthritis (Case report), 185
Did he fall or was he pushed? (Case of the month), 199
Computed tomography of the post-operative lumbar spine: the need for, and optimal dose of, intravenous contrast medium, 215
The case of the forgetful gardener (Case of the month), 293

INDEX TO SUBJECTS—continued

The role of delayed computed tomographic scanning using high doses of contrast material in detecting cerebral demyelination in patients with multiple sclerosis in relapse and remission (Short communication), 295
Intravenous digital subtraction angiography in intracranial aneurysms, 323
Cortical blindness in toxaemia of pregnancy: findings on computed tomography, 347
Demonstration of pulsatile cerebrospinal-fluid flow using magnetic resonance phase imaging, 423
The cribriform plate: a sanctuary site for meningeal leukaemia, 469
Magnetic resonance flow imaging: a possible method for distinguishing communicating syringomyelia from cystic intraspinal lesions (Correspondence), 517
Comparative trial of Hexabrix (320 mg iodine/ml), iohexol (300 mg iodine/ml) and Iopamiron (300 mg iodine/ml) in cerebral and spinal angiography: a preliminary report, 671
Magnetic resonance imaging of syringomyelia occurring after operation on spinal intramedullary tumours by Cavitron ultrasonic aspirator (Case report), 701
Neuropathic arthropathy as a complication of post-traumatic syringomyelia (Case report), 702
Pituitary size in hypothyroidism as determined by computed tomography (Short communication), 935
Case of the month:lipoma of the corpus callosum (Correspondence), 940
Idiopathic spinal arachnoid cyst and syringomyelia (Case report), 1023
Radiographic appearance of frontal osteomyelitis in two patients with extradural abscess (Case report), 1026
Computed tomographic myelography in the investigation of childhood scoliosis and spinal dysraphism, 1197

Cardiovascular system

Ultrasonic localisation of a non-opaque intravascular catheter fragment (Case report), 91
Colour display of quantitative blood flow and cardiac anatomy in a single magnetic resonance cine loop, 105
Neurological morbidity of arch and carotid arteriography in cerebrovascular disease. The influence of contrast medium and radiologist, 117
Limb muscle compression: an alternative technique for intravenous digital subtraction angiography, 123
Comparison of low-osmolar contrast media in paediatric cardiac angiography, 133
Anuria: an unusual presentation of aortic dissection (diagnosed by ultrasound) (Case report), 195
Varicography in the management of primary varicose veins, 235
Superior mesenteric artery aneurysm diagnosed by ultrasound (Case report), 287
Translumbar aortography (Correspondence), 304
Identification of intracardiac thrombus: comparison of computed tomography and cross-sectional echocardiography, 327
Magnetic resonance imaging of the dissected thoracic aorta (Case report), 499
Ultrasound diagnosis of profunda femoris pseudo-aneurysm following nail-plate fixation of a transcervical femoral fracture (Case report), 502
Pulmonary embolism, haematemesis and the Gunther vena caval filter (Case report), 595
Peripheral versus central venous contrast injection in digital subtraction angiography (Correspondence), 601
Breast 'abscess': an unusual complication of catheterisation of the subclavian vein, 773
Peripheral angiography in a standard fluoroscopy room (Technical note), 923
A comparison of angiographic and electrocardiographically gated computed tomographic measurements of left-ventricular function, 969
The measurement of heart size in the antero-posterior chest radiograph, 981
Position of the superior mesenteric artery on computed tomography and its relationship to retroperitoneal disease, 997
A set of X-ray test objects for image quality control in digital subtraction fluorography. I: design considerations, 1001
A set of X-ray test objects for image quality control in digital subtraction fluorography. II: application and interpretation of results, 1011
The accuracy of digital subtraction angiography for the quantification of atherosclerosis, 1083
A case of mitozantrone-associated cardiomyopathy without prior anthracycline therapy (Case report), 1125
Asymmetrical pulmonary oedema due to Swyer-James syndrome (Case report), 1126
All's well that ends well (Case of the month), 1231
Translumbar aortography (Correspondence), 1237

Respiratory tract

Evaluation of pulmonary parenchymal disease by magnetic resonance imaging, 223
Rounded opacity in a young man's chest (Case of the month), 411
Pulmonary embolism, haematemesis and the Gunther vena caval filter (Case report), 595
The pre-operative chest radiograph (Case of the month), 597
Negative gallium scan in an AIDS patient with *Pneumocystis* pneumonia (Case report), 714
Should aminophylline be used in acute bronchospasm induced by contrast media? (Correspondence), 725
Radiological features of systemic mast-cell disease, 765
The visible wall of a main bronchus: a new radiological sign of pneumomediastinum, 877
Radionuclide investigations of the lung, February 11, 1987 (BIR Proceedings), 1044
Asymmetrical pulmonary oedema due to Swyer-James syndrome (Case report), 1126
Congenital cystic adenomatoid malformation of the lung in a young adult (Case report), 1128
Quantitative assessment of lung damage due to bleomycin using CT, 1205

Digestive tract

The detection of massive colonic haemorrhage by selective coeliac arteriography (Case report), 190
The ultrasonic demonstration of acute multiple gastric ulcers in a child (Case report), 290
Clinical use of Hexabrix for radiological evaluation of leakage from the upper gastrointestinal tract based on experimental study, 343
Multiple ileal carcinoid tumours (Case report), 402

INDEX TO VOLUME 60

Barium embolisation during barium enema examination: a report of a case and a review of the literature (Case report), 404
Ultrasound examination of the paediatric 'acute abdomen': preliminary findings (Short communication), 414/Buscopan and glaucoma (Correspondence), 417
Allergic reaction to Buscopan (Correspondence), 417
Endoscopy and its relationship to radiology, January 16, 1986 (BIR Proceedings), 419
Upper gastrointestinal endoscopic ultrasonography in gastroenterology, 429
Demonstration of a lactobezoar by ultrasound (Case report), 506
The radiological findings in torsion of an appendix epiploica (Case report), 508
An epidemic tumour (Case of the month), 511
Inadvertent inflation of the balloon: a rare but serious complication of Miller-Abbott intubation, 547
Pulmonary embolism, haematemesis and the Gunther vena caval filter (Case report), 595
Dysfunction of the pharyngo-oesophageal segment in patients with normal opening of the upper oesophageal sphincter: a cineradiographic study, 637
Heterotopic gastric mucosa presenting as small-bowel obstruction (Case report), 710
The case of the bloated nurse (Case of the month), 721
Quantitative magnetic resonance imaging in rectal carcinoma, 761
Radiological features of systemic mast-cell disease, 765
Gallbladder carcinoma in association with polyposis coli (Case report), 771
An unusual case of gastrointestinal haemorrhage (Case of the month), 933
Radiology of normal and abnormal gastric mucus, 987
Congenital diaphragmatic hernia: the prognostic significance of the site of the stomach, 993
Position of the superior mesenteric artery on computed tomography and its relationship to retroperitoneal disease, 997
A simple technique for double-contrast oesophagrams (Technical note), 1021
Appendix mass in AIDS? (Case report), 1030
Percutaneous gastrostomy and gastro-jejeunostomy, 1067
Submucosal gastric haematoma: a case report and review of the literature, 1132
Detection of mesenteric involvement in sarcoidosis using computed tomography (Case report), 1135
The radiological findings in syphilitic proctitis (Case report), 1137
The use of endoscopic ultrasound and laser photocoagulation in the treatment of gastrointestinal tract tumours: early experience (Short communication), 1141
The effect of oral magnesium-containing bowel preparation agents on the mucosal coating by barium sulphate suspensions, 1215
Barium embolisation during enema examination in colitis (Correspondence), 1236

Liver and biliary tract, spleen, pancreas

A rational approach to the investigation of the gallbladder (Correspondence), 100
Evaluation of subjective assessment of liver function from radionuclide images, 127
Wandering spleen (Case report), 188
Quantitative tissue characterisation in pancreatic disease using magnetic resonance imaging, 333
Dehydration, antidiuretic hormone and the intravenous urogram, 445
Subepithelial pyeloureteric lesions in patients with nephrostomy tubes, 449
Prominent collateral vein in portal hypertension mimicking liver tumours: a pitfall in computed tomography, 531
Delineation of the spleen by a combination of proliposomes with water-soluble contrast media: an experimental study using computed tomography, 535
The 'shrunken' pancreas: a morphological variant of idiopathic chronic pancreatitis, 543
Computed tomography of vinyl-chloride-induced angiosarcoma of liver (Case report), 593
The importance of appropriate frequency selection in sonographic gallstone detection, 645
Ultrasonographic patterns of focal hepatic and splenic lesions in Hodgkin's and non-Hodgkin's lymphoma, 655
Simulated splenic rupture on computed tomography (Case report), 713
Radiological features of systemic mast-cell disease, 765
Gallbladder carcinoma in association with polyposis coli (Case report), 771
Detection of splenosis by radionuclide scanning, 873
Hodgkin's disease in a patient with polysplenia (Case report), 929
Effect of cirrhosis on accuracy of ^{99}Tc^{m} tin colloid scintigraphy and ultrasound scanning in diagnosis of hepatocellular carcinoma, 1221
An unusual case of haemobilia (Case report), 1228

Urinary tract

The case of the recalcitrant Welshman (Case of the month), 93
Staging of prostatic carcinoma with radionuclide bone scintigraphy and lymphography, 79
Anuria: an unusual presentation of aortic dissection (diagnosed by ultrasound) (Case report), 195
Changes in transplanted kidney volume measured by ultrasound, 525
Improved localisation of the proximal end of antegrade ureteric stents (Technical note), 589
A new technique for renal allograft biopsy (Short communication), 599
A comparison of technetium-99m-thiodiglycolic acid and iodine-123-hippuran in the evaluation of equivocal upper urinary tract obstruction, 661
Misleading technetium-99m DTPA renogram in renal carcinoma (Case report), 717
Asymptomatic abdominal mass in a child (Case of the month), 775
Financial considerations of contrast media in intravenous urography (Correspondence), 780
An evaluation of radionuclide tomography in detecting renal space-occupying lesions (Correspondence), 780
Measurement of relative renal function. A comparison of methods and assessment of reproducibility, 861
The renal parenchymal junctional line in children: ultrasonic frequency and appearances, 865
The importance of using anterior and posterior

INDEX TO SUBJECTS—continued

views in the calculation of differential renal function using ^{99}Tc^{m}-DMSA, 869
Uroradiology update, January 15, 1987 (BIR Proceedings), 945
Demonstration of a matrix calculus using computed tomography (Case report), 1028
Real-time ultrasound measurement of bladder volume: a comparative study of three methods, 1063

Haemopoietic, lymphatic, reticulo-endothelial system
Staging of prostatic carcinoma with radionuclide bone scintigraphy and lymphography, 79
Lymph-node calcification in Lennert's lymphoma (Case report), 1131
Regression of the radiological changes of Gaucher's disease following bone marrow transplantation, 1189

Reproductive system
Scrotal ultrasonography: a clinical evaluation, 649
Pitfalls in interpretation of computed tomography prior to second-look laparotomy in patients with ovarian cancer, 975
Sclerosing stromal tumour of the ovary (Case report), 1031

Endocrine system
Adrenal-cell carcinoma and rhabdomyosarcoma occurring in father and daughter: 'SBLA' syndrome? (Case report), 89
Ultrasonically guided percutaneous inactivation of parathyroid tumours, 667
Pituitary size in hypothyroidism as determined by computed tomography (Short communication), 935
The role of ^{99}Tc^{m} pentavalent DMSA in the management of patients with medullary carcinoma of the thyroid, 1089
The association of post-radiation thyroid nodular disease with compensated hypothyroidism (Case report), 1223

Ear, nose, throat, mouth, eyes
Sialosis: diagnosis by computed tomography (Case report), 400
Massive hypertrophy of the lingual tonsils: an unusual cause of dysphagia (Case report), 505
Magnetic resonance imaging in the evaluation of nose and paranasal sinus disease, 957
Radiographic appearance of frontal osteomyelitis in two patients with extradural abscess (Case report), 1026
Infantile recurrent sialectasic parotitis: role of sonography and sialography in diagnosis, 1211

Breast and soft tissues
A comparative study of films and screens for mammography, 73
Unilateral juvenile hypertrophy of the breast (Case report), 193
Cancers induced and cancers detected in a mammography screening programme, 231
Unilateral breast hyperplasia in pregnancy simulating neoplasm (Case report), 407
Min-R film for mammography (Correspondence), 418
Changes in Wolfe mammographic patterns with aging, 455
Factors which influence the occurrence of vascular calcification in the breast, 457
Mammographic patterns in twin pairs discordant for breast cancer, 459
Computer aids to mammographic diagnosis, 887
Radiological interest in mammographic screening (Correspondence), 937
A lump on the thigh (Case of the month), 1035
An unusual inguinal swelling (Case of the month), 1139
Breast screening in China (Correspondence), 1237

Paediatrics
Comparison of low-osmolar contrast media in paediatric cardiac angiography, 133
Ultrasound findings in children with cystic fibrosis, 137
Unilateral juvenile hypertrophy of the breast (Case report), 193
The ultrasonic demonstration of acute multiple gastric ulcers in a child (Case report), 290
Ultrasound examination of the paediatric 'acute abdomen': preliminary findings (Short communication), 414
Congenital bilateral glenoid hypoplasia: a report of four cases (Case report), 705
Metaphyseal dyschondroplasia with cone-shaped epiphyses (Case report), 707
The renal parenchymal junctional line in children: ultrasonic frequency and appearances, 865
Congenital diaphragmatic hernia: the prognostic significance of the site of the stomach, 993
Use of a microcomputer for the estimation of X-ray dose received by the fetus (Technical note), 1119
Regression of the radiological changes of Gaucher's disease following bone marrow transplantation, 1189
Computed tomographic myelography in the investigation of childhood scoliosis and spinal dysraphism, 1197
Infantile recurrent sialectasic parotitis: role of sonography and sialography in diagnosis, 1211

Contrast media and other drugs
Neurological morbidity of arch and carotid arteriography in cerebrovascular disease. The influence of contrast medium and radiologist, 117
Comparison of low-osmolar contrast media in paediatric cardiac angiography, 133
Iodinated contrast agents as 'radiosensitisers' (Short communication), 201
Clinical use of Hexabrix for radiological evaluation of leakage from the upper gastrointestinal tract based on experimental study, 343
Buscopan and glaucoma (Correspondence), 417
Allergic reaction to Buscopan (Correspondence), 417
Dehydration, antidiuretic hormone and the intravenous urogram, 445
Delineation of the spleen by a combination of proliposomes with water-soluble contrast media: an experimental study using computed tomography, 535
Comparative trial of Hexabrix (320 mg iodine/ml), iohexol (300 mg iodine/ml) and Iopamiron (300 mg iodine/ml) in cerebral and spinal angiography: a preliminary report, 671
The non-ionic dimers: a new class of contrast agent (Correspondence), 728
Financial considerations of contrast media in intravenous urography (Correspondence), 780

INDEX TO VOLUME 60

The effect of oral magnesium-containing bowel preparation agents on the mucosal coating by barium sulphate suspensions, 1215
Barium embolisation during enema examination in colitis (Correspondence), 1236

Apparatus and technical aspects
A comparative study of films and screens for mammography, 73
Min-R film for mammography (Correspondence), 418
Rapid slide reproduction of text and radiographs (Technical note), 493
Digital ionography: preliminary results (Short communication), 515
A new technique for renal allograft biopsy (Short communication), 599
Validation of a digital videodensitometric program analysis for measurement of left ventricular ejection fraction, 693
Developer temperature in diagnostic departments (Correspondence), 781
Computer aids to mammographic diagnosis, 887
The Sheffield stereotactic radiosurgery unit: physical characteristics and principles of operation, 897
Peripheral angiography in a standard fluoroscopy room (Technical note), 923
The measurement of heart size in the antero-posterior chest radiograph, 981
A set of X-ray test objects for image quality control in digital subtraction fluorography. I: design considerations, 1001
A set of X-ray test objects for image quality control in digital subtraction fluorography. II: application and interpretation of results, 1011
Use of a simple Leeds test object for rapid assessment of image intensifiers (Technical note), 1019
Evaluating and comparing imaging techniques: a review and classification of study designs, 1071
The accuracy of digital subtraction angiography for the quantification of atherosclerosis, 1083
Use of a microcomputer for the estimation of X-ray dose received by the fetus (Technical note), 1119

Organisation and statistics
The assurance of quality in medical imaging, May 21, 1986 (BIR Proceedings), 305
Variation in repeat rates between 18 radiology departments, 463
Rapid slide reproduction of text and radiographs (Technical note), 493
Analysis of wasted X-ray films: experience in two Kuwait hospitals (Short communication), 513
Digital ionography: preliminary results (Short communication), 515
Out-of-hours radiology: a suitable case for audit? 553
The assurance of quality in medical imaging, May 21, 1986 (BIR Proceedings), 305
Influence on patient management of general practitioner direct access to radiological services, 893
A review of cervical-spinal radiographs in casualty patients, 1059

Computed tomography
(*head*)
The role of delayed computed tomographic scanning using high doses of contrast material in detecting cerebral demyelination in patients with multiple sclerosis in relapse and remission (Short communication), 295
Cortical blindness in toxaemia of pregnancy: findings on computed tomography, 347
Sialosis: diagnosis by computed tomography (Case report), 400
Pituitary size in hypothyroidism as determined by computed tomography (Short communication), 935

Computed tomography
(*whole body*)
The case of the recalcitrant Welshman (Case of the month), 93
Computed tomography of the post-operative lumbar spine: the need for, and optimal dose of, intravenous contrast medium, 215
Identification of intracardiac thrombus: comparison of computed tomography and cross-sectional echocardiography, 327
Abdominal computed tomography in teratoma of the testis: its accuracy in Stage I disease and an assessment of the distribution of retroperitoneal lymph-node metastases in other stages of the disease, 487
Avoidance of ring artefacts in lumbar spine computed tomography in obese patients (Correspondence), 518
Prominent collateral vein in portal hypertension mimicking liver tumours: a pitfall in computed tomography, 531
Delineation of the spleen by a combination of proliposomes with water-soluble contrast media: an experimental study using computed tomography, 535
Computed tomography of vinyl-chloride-induced angiosarcoma of liver (Case report), 593
Simulated splenic rupture on computed tomography (Case report), 713
Asymptomatic abdominal mass in a child (Case of the month), 775
A comparison of angiographic and electrocardiographically gated computed tomographic measurements of left-ventricular function, 969
Pitfalls in interpretation of computed tomography prior to second-look laparotomy in patients with ovarian cancer, 975
Position of the superior mesenteric artery on computed tomography and its relationship to retroperitoneal disease, 997
Demonstration of a matrix calculus using computed tomography (Case report), 1028
Sclerosing stromal tumour of the ovary (Case report), 1031
Detection of mesenteric involvement in sarcoidosis using computed tomography (Case report), 1135
Computed tomographic myelography in the investigation of childhood scoliosis and spinal dysraphism, 1197
Quantitative assessment of lung damage due to bleomycin using CT, 1205

Computed tomography
(*apparatus and technical aspects*)
The development of a system for transillumination computed tomography, 375

Interventional radiology
Ultrasonic localisation of a non-opaque intravascular catheter fragment (Case report), 91

Electron microscopy of ultrasound-guided fine-needle biopsy specimens, 351
Improved localisation of the proximal end of antegrade ureteric stents (Technical note), 589
A new technique for renal allograft biopsy (Short communication), 599
Interventional radiology of the spine, October 16, 1986 (BIR Proceedings), 603
Percutaneous gastrostomy and gastro-jejeunostomy, 1067
The use of endoscopic ultrasound and laser photocoagulation in the treatment of gastrointestinal tract tumours: early experience (Short communication), 1141

ULTRASOUND
Clinical aspects
Ultrasonic localisation of a non-opaque intravascular catheter fragment (Case report), 91
Ultrasound findings in children with cystic fibrosis, 137
Anuria: an unusual presentation of aortic dissection (diagnosed by ultrasound) (Case report), 195
Safety of diagnostic ultrasound, May 15, 1986 (BIR Proceedings), 207
Superior mesenteric artery aneurysm diagnosed by ultrasound (Case report), 287
The ultrasonic demonstration of acute multiple gastric ulcers in a child (Case report), 290
Identification of intracardiac thrombus: comparison of computed tomography and cross-sectional echocardiography, 327
Electron microscopy of ultrasound-guided fine-needle biopsy specimens, 351
Ultrasound examination of the paediatric 'acute abdomen': preliminary findings (Short communication), 414
Upper gastrointestinal endoscopic ultrasonography in gastroenterology, 429
Parathyroid sonography: diagnostic accuracy related to shape, location and texture of the gland, 439
Ultrasound diagnosis of profunda femoris pseudo-aneurysm following nail-plate fixation of a transcervical femoral fracture (Case report), 502
Demonstration of a lactobezoar by ultrasound (Case report), 506
A new method using ultrasound for measuring femoral anteversion (torsion): technique and reliability, 519
Changes in transplanted kidney volume measured by ultrasound, 525
Proceedings of The British Medical Ultrasound Society, Eighteenth Annual Meeting, December 16–18, 1986, 609
The importance of appropriate frequency selection in sonographic gallstone detection, 645
Scrotal ultrasonography: a clinical evaluation, 649
Ultrasonographic patterns of focal hepatic and splenic lesions in Hodgkin's and non-Hodgkin's lymphoma, 655
Ultrasonically guided percutaneous inactivation of parathyroid tumours, 667
Asymptomatic abdominal mass in a child (Case of the month), 775
The renal parenchymal junctional line in children: ultrasonic frequency and appearances, 865
Seeing things more clearly (1986 Mayneord Lecture), 1049
Real-time ultrasound measurement of bladder volume: a comparative study of three methods, 1063
The use of endoscopic ultrasound and laser photocoagulation in the treatment of gastrointestinal tract tumours: early experience (Short communication), 1141
Infantile recurrent sialectasic parotitis: role of sonography and sialography in diagnosis, 1211

Apparatus and technical aspects
Safety of diagnostic ultrasound, May 15, 1986 (BIR Proceedings), 207
Electron microscopy of ultrasound-guided fine-needle biopsy specimens, 351
Noise reduction in ultrasonic images by digital filtering (Technical note), 389
Upper gastrointestinal endoscopic ultrasonography in gastroenterology, 429
Proceedings of The British Medical Ultrasound Society, Eighteenth Annual Meeting, December 16–18, 1986, 609
The importance of appropriate frequency selection in sonographic gallstone detection, 645
Scrotal ultrasonography: a clinical evaluation, 649
Seeing things more clearly (1986 Mayneord Lecture), 1049

NUCLEAR MEDICINE
Clinical aspects
Staging of prostatic carcinoma with radionuclide bone scintigraphy and lymphography, 79
Evaluation of subjective assessment of liver function from radionuclide images, 127
Imaging and treatment of disseminated neuroblastoma with ^{131}I-meta-iodobenzylguanidine (Case report), 393
A photopenic lesion in osteosarcoma (Case report), 497
Absorbed dose from ^{14}C xylose and ^{14}C mannose, 563
A comparison of technetium-99m-thiodiglycolic acid and iodine-123-hippuran in the evaluation of equivocal upper urinary tract obstruction, 661
Strontium-89 radionuclide therapy: a dosimetric study using impulse response function analysis, 685
Negative gallium scan in an AIDS patient with *Pneumocystis* pneumonia (Case report), 714
Misleading technetium-99m DTPA renogram in renal carcinoma (Case report), 717
Diagnostic and therapeutic uses of radioisotopes in oncology, November 26, 1986 (BIR Proceedings), 731
Radiological features of systemic mast-cell disease, 765
An evaluation of radionuclide tomography in detecting renal space-occupying lesions (Correspondence), 780
Measurement of relative renal function. A comparison of methods and assessment of reproducibility, 861
The importance of using anterior and posterior views in the calculation of differential renal function using ^{99}Tc^{m}-DMSA, 869
Detection of splenosis by radionuclide scanning, 873
Radionuclide investigations of the lung, February 11, 1987 (BIR Proceedings), 1044
Seeing things more clearly (1986 Mayneord Lecture), 1049

INDEX TO VOLUME 60

The role of ^{99}Tc^{m} pentavalent DMSA in the management of patients with medullary carcinoma of the thyroid, 1089
Effect of cirrhosis on accuracy of ^{99}Tc^{m} tin colloid scintigraphy and ultrasound scanning in diagnosis of hepatocellular carcinoma, 1221

Apparatus and technical aspects
The associated X-ray spectra of Amersham caesium-137 afterloading sources, 175
Measurements of internal auditory meatus by polytomography. 1. Normal subjects, 209
Measurement of radiation dose to the thyroid using positron emission tomography, 245
Radiological safety: gamma camera flood sources (Technical note), 495
Three-dimensional display of data obtained by single photon emission computed tomography, 557
Measurement of relative renal function. A comparison of methods and assessment of reproducibility, 861
A method for thresholding subtracted images in radiolabelled-antibody imaging, 881
Seeing things more clearly (1986 Mayneord Lecture), 1049

NUCLEAR MAGNETIC RESONANCE
Image non-uniformity in magnetic resonance imaging: its magnitude and methods for its correction (Technical note), 83
Colour display of quantitative blood flow and cardiac anatomy in a single magnetic resonance cine loop, 105
Accuracy and precision in the measurement of relaxation times from nuclear magnetic resonance images,143
Evaluation of pulmonary parenchymal disease by magnetic resonance imaging, 223
Reproducibility of spin lattice relaxation time (T_1) measurement using an 0.08 tesla MD 800 magnetic resonance imager, 241
Quantitative tissue characterisation in pancreatic disease using magnetic resonance imaging, 333
The study of human organs by phosphorus-31 topical magnetic resonance spectroscopy, 367
Demonstration of pulsatile cerebrospinal-fluid flow using magnetic resonance phase imaging, 423
Magnetic resonance imaging of the dissected thoracic aorta (Case report), 499
Magnetic resonance flow imaging: a possible method for distinguishing communicating syringomyelia from cystic intraspinal lesions (Correspondence), 517
Magnetic resonance imaging of syringomyelia occurring after operation on spinal intramedullary tumours by Cavitron ultrasonic aspirator (Case report), 701
Quantitative magnetic resonance imaging in rectal carcinoma, 761
Case of the month: lipoma of the corpus callosum (Correspondence), 940
Practical aspects of magnetic resonance imaging, January 14, 1987 (BIR Proceedings), 942
Magnetic resonance imaging in the evaluation of nose and paranasal sinus disease, 957
Accuracy and precision in the measurement of relaxation times from nuclear magnetic resonance images (Correspondence), 1041
Seeing things more clearly (1986 Mayneord Lecture), 1049
Increased potential for tissue discrimination in quantitative magnetic resonance imaging (Correspondence), 1142

PHYSICS
Applied to radiodiagnosis
A comparative study of films and screens for mammography, 73
Tissue analysis by dual-energy computed tomography (Correspondence), 726A set of X-ray test objects for image quality control in digital subtraction fluorography. I: design considerations, 1001
A set of X-ray test objects for image quality control in digital subtraction fluorography. II: application and interpretation of results, 1011
Use of a simple Leeds test object for rapid assessment of image intensifiers (Technical note), 1019
Use of a microcomputer for the estimation of X-ray dose received by the fetus (Technical note), 1119
Picture archiving and communications systems, February 25, 1987 (BIR Proceedings), 1144

Applied to radiotherapy
The associated X-ray spectra of Amersham caesium-137 afterloading sources, 175
A minimum data input computer program for Selectron treatment calculation (Technical note), 181
Improved total-body irradiation dosimetry, 269
Strontium-89 radionuclide therapy: a dosimetric study using impulse response function analysis, 685
The Sheffield stereotactic radiosurgery unit: physical characteristics and principles of operation, 897
Divergence of opinion over the linear-quadratic model (Correspondence), 1042
Average soft-tissue and bone models for use in radiation dosimetry, 907

Applied to nuclear medicine
The associated X-ray spectra of Amersham caesium-137 afterloading sources, 175
Measurement of radiation dose to the thyroid using positron emission tomography, 245

RADIOTHERAPY
Results and clinical aspects
Growing points in radiotherapy since 1930. (65th Mackenzie Davidson Memorial Lecture, 1984), 51
Staging of prostatic carcinoma with radionuclide bone scintigraphy and lymphography, 79
Clinically derived dose–effect relationship for hyperthermia given in combination with low-dose radiotherapy (Correspondence), 100
Strontium-89 therapy: strontium kinetics and dosimetry in two patients treated for metastasising osteosarcoma, 253
Local control of Ewing's sarcoma: an analysis of 67 patients, 261
The implications of *in-vitro* radiation–survival curves for the optimal scheduling of total-body irradiation with bone marrow rescue in the treatment of leukaemia, 279
Low-dose total-body irradiation in the management of refractory rheumatoid arthritis (Short communication), 297
What minimum number of fractions is required with high dose-rate remote afterloading? (Correspondence), 300

Proceedings of the EORTC Heavy Particle Therapy Group, May 1–3, 1986, 309
The relationship between the bladder and the cervix in patients undergoing intracavitary therapy, 355
On-line measurement of field placement errors in external beam radiotherapy, 361
A comparison of clonogenic and radionuclide uptake assays for determining the radiation response of human small-cell lung cancer xenografts and cell lines, 381
Imaging and treatment of disseminated neuroblastoma with ^{131}I-meta-iodobenzylguanidine (Case report), 393
The cribriform plate: a sanctuary site for meningeal leukaemia, 469
Brachytherapy of tumour recurrences in the region of the pharynx and oral cavity by means of a remote-controlled afterloading technique, 477
Abdominal computed tomography in teratoma of the testis: its accuracy in Stage I disease and an assessment of the distribution of retroperitoneal lymph-node metastases in other stages of the disease, 487
Diagnostic and therapeutic uses of radioisotopes in oncology, November 26, 1986 (BIR Proceedings), 731
Improved external beam radiotherapy for the treatment of retinoblastoma, 753
Short and long fractionated schedules in radiotherapy and a proposed improvement (Short communication), 777
Early radiation swelling remains a problem in the management of paediatric brain tumours (Case report), 931
Intracavitary irradiation of endometrial cancer of large uteri using a two-phase afterloading technique, 1093
The use of endoscopic ultrasound and laser photocoagulation in the treatment of gastrointestinal tract tumours: earl experience (Short communication), 1141
The association of post-radiation thyroid nodular disease with compensated hypothyroidism (Case report), 1223
Skin reaction following aminoglutethimide and radiotherapy (Case report), 1226
An unusual case of haemobilia (Case report), 1228

Apparatus and technical aspects
Growing points in radiotherapy since 1930. (65th Mackenzie Davidson Memorial Lecture, 1984), 51
A simple design for an accurate uniformity phantom (Correspondence), 101
A minimum data input computer program for Selectron treatment calculation (Technical note), 181
Amersham afterloading system (Correspondence), 205
Strontium-89 therapy: strontium kinetics and dosimetry in two patients rteated for metastasising osteosarcoma, 253
Improved total-body irradiation dosimetry, 269
Proceedings of the EORTC Heavy Particle Therapy Group, May 1–3, 1986, 309
The relationship between the bladder and the cervix in patients undergoing intracavitary therapy, 355
On-line measurement of field placement errors in external beam radiotherapy, 361
Brachytherapy of tumour recurrences in the region of the pharynx and oral cavity by means of a remote-controlled afterloading technique, 477
Geometry adopted by Manchester radium applicators in intracavitary treatment for carcinoma cervix uteri, 481
Invisible field skin-marking on radiotherapy patients (Correspondence), 726
Diagnostic and therapeutic uses of radioisotopes in oncology, November 26, 1986 (BIR Proceedings), 731
Improved external beam radiotherapy for the treatment of retinoblastoma, 753
The Sheffield stereotactic radiosurgery unit: physical characteristics and principles of operation, 897
Modification of the Selectron standard applicator for gynecological treatment (Correspondence), 1238

CANCER CHEMOTHERAPY
Cancer: the failure of treatment (1986 Silvanus Thompson Memorial Lecture), 735
Skin reaction following aminoglutethimide and radiotherapy (Case report), 1226

RADIOBIOLOGY
Applied to radiotherapy
Progress in tumour radiobiology: radiobiology work-in-progress, May 16, 1986 (BIR Proceedings), 102
The implications of *in-vitro* radiation–survival curves for the optimal scheduling of total-body irradiation with bone marrow rescue in the treatment of leukaemia, 279
A comparison of clonogenic and radionuclide uptake assays for determining the radiation response of human small-cell lung cancer xenografts and cell lines, 381
Limitations to the killing of tumours using radiolabelled antibodies, 567
Dose-rate effects in normal and malignant cells of human origin, 573
Short and long fractionated schedules in radiotherapy and a proposed improvement (Short communication), 777
Change in therapeutic gain with photon contamination in a neutron beam (Correspondence), 937
The influence of field size on the late tolerance of the rat spinal cord to single doses of X rays, 1099

Effects of radiation quality
Progress in tumour radiobiology: radiobiology work-in-progress, May 16, 1986 (BIR Proceedings), 102
The effect of mixed fractionation with X rays and neutrons on tumour growth delay and skin reactions in mice, 583
Change in therapeutic gain with photon contamination in a neutron beam (Correspondence), 937

Fractionation studies
Progress in tumour radiobiology: radiobiology work-in-progress, May 16, 1986 (BIR Proceedings), 102
Dose-rate effects in normal and malignant cells of human origin, 573
The effect of mixed fractionation with X rays and neutrons on tumour growth delay and skin reactions in mice, 583
Accelerated fractionation and hyperfractionation: experimental and clinical, November 14, 1986 (BIR Proceedings), 605

INDEX TO VOLUME 60

Hyperthermia and irradiation

Progress in tumour radiobiology: radiobiology work-in-progress, May 16, 1986 (BIR Proceedings), 102

Sensitisers and protectors

The relationship between the misonidazole 'pre-incubation' effect and misonidazole-induced depletion of cellular GSH (Short communication), 96
Progress in tumour radiobiology: radiobiology work-in-progress, May 16, 1986 (BIR Proceedings), 102
Iodinated contrast agents as 'radiosensitisers' (Short communication), 201
The effect of ethanol on the radiation response of CHO-K1 cells, 577
Hypoxic radiosensitisation by FLAP (Correspondence), 601
Compartmentalised depletion of glutathione in cells treated with buthionine sulphoximine (Short communication), 723
Uptake and additivity of the radiosensitising effects of Ro 03 8799 and SR 2508 in mammalian cells *in vitro* (Short communication), 1233

Other studies

Progress in tumour radiobiology: radiobiology work-in-progress, May 16, 1986 (BIR Proceedings), 102
Radiation response of multicellular spheroids initiated from five human melanoma xenograft lines (Correspondence), 303
A comparison of clonogenic and radionuclide uptake assays for determining the radiation response of human small-cell lung cancer xenografts and cell lines, 381
Vascular injury in the mouse rectum after irradiation and cis-diamminedichloroplatinum (II) (Short communication), 1037
Dose-dependent and time-dependent changes in the choroid plexus of the irradiated rat brain, 1109

HYPERTHERMIA

Clinically derived dose–effect relationship for hyperthermia given in combination with low-dose radiotherapy (Correspondence), 100

HAZARDS AND RADIATION PROTECTION

Cancer induction and non-stochastic effects, 1
Hereditary effects of radiation: some evidence from animal experiments (Abstract), 16
Irradiation of the embryo and fetus, 17
Principles of the International Commission on Radiological Protection system of dose limitation, 32
Practical implementation of ICRP recommendations, 38
Radiation risks in perspective, 42
Patient doses and risks from diagnostic radiology in North-east Italy, 155
An investigation into the levels of radiation exposure in diagnostic examinations involving fluoroscopy, 167
Scattered radiation reaching doors and windows of diagnostic X-ray rooms (Technical note), 179
The lead apron: room for improvement? (Short communication), 203
TLD patient monitoring (Correspondence), 205
Cancers induced and cancers detected in a mammography screening programme, 231
Measurement of radiation dose to the thyroid using positron emission tomography, 245
Improved total-body irradiation dosimetry, 269
The assurance of quality in medical imaging, May 21, 1986 (BIR Proceedings), 305
Variation in repeat rates between 18 radiology departments, 463
Radiological safety: gamma camera flood sources (Technical note), 495
Analysis of wasted X-ray films: experience in two Kuwait hospitals (Short communication), 513
Inadvertent inflation of the balloon: a rare but serious complication of Miller-Abbott intubation, 547
Absorbed dose from ^{14}C xylose and ^{14}C mannose, 563
The prediction of the relative toxicities of radium 224 and of radium 226 in the bones of mice using Monte Carlo techniques, 677
Valuing the man-sievert in X-ray diagnosis, 681
Should aminophylline be used in acute bronchospasm induced by contrast media? (Correspondence), 725
The position of the personal dosemeter in diagnostic X-ray practice (Correspondence), 728
Regulations and guidance on radiation protection, October 2, 1986 (BIR Proceedings), 729
Radiation safety in the nuclear medicine department: impact of the UK *Ionising Radiations Regulations*, 915
The application of cost–benefit analysis when considering action to reduce environmental dose rates in hospitals, 919
Severe mental retardation in Japanese bomb survivors irradiated *in utero*: a postscript (Correspondence), 939
A set of X-ray test objects for image quality control in digital subtraction fluorography. I: design considerations, 1001
A set of X-ray test objects for image quality control in digital subtraction fluorography. II: application and interpretation of results, 1011
Use of a simple Leeds test object for rapid assessment of image intensifiers (Technical note), 1019
Use of a microcomputer for the estimation of X-ray dose received by the fetus (Technical note), 1119
The Chernobyl reactor accident: the impact on the United Kingdom (1987 Mayneord Lecture), 1147
Medical and radiobiological basis of radiation accident management, 1159
Medical basis for the establishment of intervention levels, 1163
Experience of a specialised centre in the organisation of medical care of persons exposed during a nuclear reactor accident, 1169
The role of NHS hospitals in the preparedness for nuclear accidents, 1171
United Kingdom nuclear reactor design and operation, 1174
Emergency planning, 1177
Nuclear emergencies: medical preparedness, 1180
Reactor accidents in perspective, 1182

LECTURES AND ADDRESSES

Growing points in radiotherapy since 1930. (65th Mackenzie Davidson Memorial Lecture, 1984), 51
Cancer: the failure of treatment (1986 Silvanus Thompson Memorial Lecture), 735
he institute at 90: a time for reappraisal? (1986/87 Presidential Address), 947

INDEX TO SUBJECTS—continued

Seeing things more clearly (1986 Mayneord Lecture), 1049
The Chernobyl reactor accident: the impact on the United Kingdom (1987 Mayneord Lecture), 1147

EDUCATION

The case of the recalcitrant Welshman (Case of the month), 93
Did he fall or was he pushed? (Case of the month), 199
The case of the forgetful gardener (Case of the month), 293
Rounded opacity in a young man's chest (Case of the month), 411
Rapid slide reproduction of text and radiographs (Technical note), 493
An epidemic tumour (Case of the month), 511
The pre-operative chest radiograph (Case of the month), 597
The case of the bloated nurse (Case of the month), 721
Asymptomatic abdominal mass in a child (Case of the month), 775
An unusual case of gastrointestinal haemorrhage (Case of the month), 933
A lump on the thigh (Case of the month), 1035
An unusual inguinal swelling (Case of the month), 1139
All's well that ends well (Case of the month), 1231
A quarter of a century ago. (The first of a series of articles on the history of radiology, by the editors), 1239

PROCEEDINGS

Progress in tumour radiobiology: radiobiology work-in-progress, May 16, 1986, 102
Safety of diagnostic ultrasound, May 15, 1986, 207
The assurance of quality in medical imaging, May 21, 1986, 305
EORTC Heavy Particle Therapy Group, May 1–3, 1986, 309
Endoscopy and its relationship to radiology, January 16, 1986, 419
Interventional radiology of the spine, October 16, 1986, 603
Accelerated fractionation and hyperfractionation: experimental and clinical, November 14, 1986, 605
The British Medical Ultrasound Society, Eighteenth Annual Meeting, December 16–18, 1986, 609
Regulations and guidance on radiation protection, October 2, 1986, 729
Diagnostic and therapeutic uses of radioisotopes in oncology, November 26, 1986, 731
Radiology '87: 45th Annual Congress, April 1–3, 1987, 783
Practical aspects of magnetic resonance imaging, January 14, 1987, 942
Uroradiology update, January 15, 1987, 945
Radionuclide investigations of the lung, February 11, 1987, 1044
Picture archiving and communications systems, February 25, 1987, 1144

OBITUARIES

J. S. Mitchell, B25
R. W. McNabb, B27
W. J. Stripp, B49
P. Burch, B54
B. Page, B54
J. W. D. Bull, B62
N. A. Lewtas, B77

AWARDS

BIR Awards 1987, B21, B37

BOOK REVIEWS

Alderson, A. R. (Ed.). *Dosimetry and clinical uses of afterloading systems*, 676
Allan, L. D. *Manual of fetal echocardiography*, 1058
Amplatz, K., Moller, J. H. and Castañeda-Zuniga, W. R. *Radiology of congenital heart disease, Vol. 1*, 980
Annonier, C. *Female breast examination: a theoretical and practical guide to breast diagnosis*, 720
Ansell, G. *Notes on radiologic emergencies, 3rd edit.*, 534
Axenrod, T. and Ceccarelli, C. *NMR in living systems*, 342
Bassett, L. W., Gold, R. H. and Kimme-Smith, C. *Hand-held and automated breast ultrasound*, 322
Bernstein, E. F. (Ed.). *Noninvasive diagnostic techniques in vascular disease, 3rd edit.*, 700
Berquist, T. H. (Ed.). *Imaging of orthopedic trauma and surgery*, 492
Berquist, T. H., Ehman, R. L. and Richardson, M. L. (Eds). *Magnetic resonance of the musculoskeletal system*, 956
Berquist, T. H., Ehman, R. L. and May, G. R. *Pocket atlas of MRI body anatomy*, 1062
Bolla, M., Racinet, C. and Vrousos, C. (Eds). *Endometrial cancers. Fifth cancer research workshop, Grenoble 1985*, 178
Bories, J. (Ed.). *Cerebral ischaemia. A neurological study*, 720
Bruneton, J.-N. and Schneider, M. (Eds). *Radiology of lymphomas*, 1000
Buist, T. A. S. (Ed.). *Invasive radiology. Clinics in gastroenterology, Vol. 14, No. 2*, 342
Burrows, E. H. *Pioneers and early years. A history of British radiology*, 530
Capra, L. G. *Care of the cancer patient, 2nd edit.*, 1196
Chesney, D. N. and Chesney M. O. *Care of the patient in diagnostic radiography, 6th edit.*, 410
Chesney D. N. and Chesney, M. O. *A radiographer's handbook of hospital practice*, 462
Chien, S. and Ho, C. (Eds). *NMR in Biology and Medicine*, 322
Chudleigh, P. and Pearce, J. M. *Obstetric ultrasound. How, why and when*, 892
Daneman, A. *Pediatric body CT*, 1058
de Slepte, R. G. M., Valk, J., Lohman, A. H. M. and Zonneveld, F. W. *Cisternographic anatomy of the posterior cranial fossa. High resolution CT and MRI study*, 112
Deeley, T. J. *Wilhelm Conrad Röntgen. His life and the new kind of rays*, 454
Deter, R. L., Harrist, R. B., Birnholz, J. C. and Hadlock, F. P. *Quantitative obstetrical ultrasonography*, 354
Dihlmann, W. *Radiologic atlas of rheumatic diseases*, 184
Eisenberg, R. L. *Diagnostic imaging in surgery*, 1082
English, R. J. and Brown, S. E. *SPECT. Single-photon emission computed tomography: a primer*, 676
Eyes, B. E. and MacFarlane, I. A. *Radiology of diabetes*, 876

INDEX TO VOLUME 60

Faerber, E. N. *Cranial computed tomography in infants and children*, 374

Federle, M. P. and Brant-Zawadzki, M. *Computed tomography in the evaluation of trauma, 2nd edit.*, 492

Fogelman, I. (Ed.). *Bone scanning in clinical practice*, 872

Giuliani, E. R. (Ed.). *Two dimensional real time ultrasonic imaging of the heart*, 142

Goddard, P. R. *Diagnostic imaging of the chest*, 956

Goldman, M. *A guide to the X-ray department, 2nd edit.*, 126

Gough, M. H., Gear, M. W. L. and Daar, A. S. *Plain X-ray diagnosis of the acute abdomen*, 1220

Grainger, R. G. and Allison, D. J. (Eds). *Diagnostic radiology (an Anglo-American textbook of imaging)*, 126

Grant, E. G. (Ed.). *Neurosonography of the pre-term neonate*, 1230

Grech, P., Martin, T. J., Barrington, N. A. and Ell, P. J. *Diagnosis of metabolic bone disease*, 284

Greenwald, P. and Sondik, E. J. (Eds). *NCI Monographs 1986 No. 2. Cancer control objectives for the nation: 1985–2000*, 720

Grunebaum, M. *Differential diagnosis in paediatric radiology*, 284

Han, M.-C. and Kim, C.-W. *Sectional human anatomy*, 524

Hand, J. W. and James, J. R. (Eds). *Physical techniques in clinical hyperthermia*, 1124

Hansmann, M., Hackelöer, B.-J. and Staudach, A. (Eds). *Ultrasound diagnosis in obstetrics and gynaecology*, 892

Hayden, C. K. Jr and Swischuk, L. E. *Pediatric ultrasonography*, 1058

Hill, C. R. (Ed.). *Physical principles of medical ultrasonics*, 322

Hope-Stone, H. F. (Ed.). *Radiotherapy in clinical practice*, 582

Hospital Physicists' Association. *Measurement of the performance characteristics of diagnostic X-ray systems used in medicine. Part V: Conventional tomographic equipment*, 284

Hricak, H. (Ed.). *Genito-urinary ultrasound. Clinics in diagnostic ultrasound 18*, 136

Huhta, J. C. *Pediatric imaging/Doppler ultrasound of the chest: extracardiac diagnosis*, 956

Hukins, D. W. L. and Mulholland, R. C. (Eds). *Back pain: methods for clinical investigation and assessment*, 410

ICRU report 41. Modulation transfer function of screen–film systems, 1118

Ischinger, T. *Practice of coronary angioplasty*, 552

Jackson, P. C. *Radionuclide imaging in medicine: theory and practice*, 422

Jones, D. G. and Wall, B. F. *Organ doses from medical X-ray examinations calculated using Monte-Carlo techniques. NRPB R186*, 1118

Just, H. and Heintzen, P. H. (Eds). *Angiocardiography. Current status and future developments*, 1062

Kathren, R. L., Baalman, R. W. and Bair, W. J. (Eds). *Herbert M. Parker: publications and other contributions to radiological and health physics*, 1000

Kisslo, J., Adams, D. and Mark, D. B. *Basic Doppler echocardiography. Clinics in diagnostic ultrasound 17*, 428

Kotler, M. N. and Steiner, R. M. (Eds). *Cardiac imaging: new technologies and clinical applications*, 980

Kressel, H. Y. (Ed.). *Magnetic resonance annual 1986*, 154

Kriegel, H., Schmahl, W., Gerber, G. B. and Stieve, F. E. *Radiation risks to the developing nervous system*, 166

Langlotz, M. Lumbar myelography with water-soluble contrast media, 350

Laszlo, J. (Ed.). *Physician's guide to cancer care complications: prevention and management. Fundamentals of cancer management, Vol. 2*, 582

Lau, L. S. W. and De Campo, J. F. *Notes on radiologic diagnosis*, 996

Maatman, G. *High-resolution computed tomography of the paranasal sinuses, pharynx and related regions*, 542

Maklad, N. F. (Ed.). *Ultrasound in perinatology*, 1230

Malfertheiner, P. and Ditschuneit, H. (Eds). *Diagnostic procedures in pancreatic disease*, 542

March, J. L. and Vannier, M. W. (Eds). *Comprehensive care for craniofacial deformities*, 448

Martin, A. and Harbison, S. A. *An introduction to radiation protection, 3rd edit.*, 366

May, G. and Gardiner, R. *Clinical imaging of the pancreas*, 1062

McBrien, D. C. H. and Slater, T. F. *Biochemical mechanisms of platinum antitumour drugs*, 1124

McKenzie, A. L., Shaw, J. E., Stephenson, S. K. and Turner, P. C. R. (Eds). *Radiation protection in radiotherapy*, 174

Megibow, A. J. and Balthazar, E. J. (Eds). *Computed tomography of the gastrointestinal tract*, 1210

Mégret, M. *Computed tomography of the cranial skeleton (face and skull). Exercises in radiological diagnosis*, 880

Meschan, I. *Roentgen signs in diagnostic imaging, Vol. 2. Appendicular skeleton*, 252

Meschan, I. *Roentgen signs in diagnostic imaging, Vol. 3*, 252

Miller, A. B. (Ed.). *Screening for cancer*, 260

Moosa, A. R., Robson, M. C. and Schimpff, S. C. (Eds). *Comprehensive textbook of oncology*, 486

Mortenson, L. E., Engstrom, P. F. and Anderson, P. N. (Eds). *Advances in cancer control. Health care financing and research*, 166

Moseley, I. *Diagnostic imaging in neurological disease*, 1082

NCI Monograph 57. *Selection, follow-up and analysis in prospective studies. A workshop*, 88

NCI Monograph 69. *Fourth symposium on epidemiology and cancer registries in the Pacific basin*, 178

NCI Monograph 70. Cusano, M. M. and Young, J. L. (Eds). *Forty-five years of cancer incidence in Connecticut 1935–79*, 174

NCI Monographs. Lippman, M. E. (Ed.). *Proceedings of the NIH Consensus Development conference on adjuvant chemotherapy and endocrine therapy for breast cancer*, 260

NCRP. *Radioactive waste. Proceedings of the 21st Annual Meeting of the NCRP, 3–4 April 1985*, 360

NCRP Report No. 85. *Mammography — a user's guide*, 82

NCRP Report No. 86. *Biological effects and exposure criteria for radiofrequency electromagnetic fields*, 922

Novelline, R. A. and Squire, L. F. Living anatomy: a working atlas using computed tomography, magnetic resonance and angiography images, 876

INDEX TO SUBJECTS—continued

NRPB. *Living with radiation*, 174

O'Reilly, P. H., Shields, R. A. and Testa, H. J. *Nuclear medicine in urology and nephrology, 2nd edit.*, 422

Ott, D. J. and Wu, W. C. (Eds.). *Polypoid disease of the colon. Emphasis on radiologic evaluation*, 476

Otto, R. Ch. and Wellauer, J. *Ultrasound-guided biopsy and drainage*, 444

Otto, R. Ch. and Higgins, C. B. (Eds). *New developments in imaging*, 996

Patel, P. R. *Multiple choice questions in radiology. With answers and explanatory comments*, 876

Peterson, S. B., Muller, R. N. and Rinck, P. A. (Eds). *An introduction to biomedical nuclear magnetic resonance*, 154

Pettersson, H., Springfield, D. S. and Enneking, W. F. *Radiological management of musculoskeletal tumours*, 860

Philips Medical Systems. *Digital subtraction angiography in clinical practice*, 122

Phillips, T. L. and Wara, W. (Eds). *Radiation oncology, vol. 2*, 1196

Prein, J., Remagen, W., Spiessl, B. and Uehlinger, E. *Atlas of the facial skeleton: odontogenic and nonodontogenic tumours*, 880

Ray, P. K. (Ed.). *Advances in immunity and cancer therapy, Vol. 2*, 1098

Reiber, J. H. C., Serruys, P. W. and Slager, C. J. *Quantitative coronary and left ventricular cineangiography*, 332

Reiber, H. H. C. and Serruys, P. W. (Eds). *State of the art in quantitative coronary arteriography*, 332

Robinson, P. J. A. (Ed.). *Nuclear gastroenterology*, 374

Sanders, R. C. *Atlas of ultrasonographic artifacts and variants*, 1210

Sanders, R. C. and Hill, M. C. (Eds). *Ultrasound annual 1985*, 136

Sanders, R. C. and Hill, M. C. (Eds). *Ultrasound annual 1986*, 354

Sauerbrei, E. E., Nguyen, K. T. and Nolan, R. L. *A practical guide to ultrasound in obstetrics and gynaecology*, 892

Schlafke-Stelson, A. T. and Watson, E. E. (Eds). *Fourth international radiopharmaceutical dosimetry symposium proceedings*, 914

Sengupta, R. P. and McAllister, V. L. *Subarachnoid haemorrhage*, 350

Serjeant, G. R. *Sickle cell disease*, 88

Shapiro, L. M., Warnes, C. A. and, K. M. *A colour atlas of angina pectoris*, 980

Shrimpton, P. C., Wall, B. F., Jones, D. G., Fisher, E. S., Hillier, M. C., Kendall, G. M. and Harrison, R. M. *A national survey of doses to patients undergoing a selection of routine X-ray examinations in English hospitals. NRPB R200*, 1118

Smith, A. D., Castañeda-Zuniga, W. R. and Bronson, J. G. (Eds). *Endourology, principles and practice*, 1034

Sorenson, J. A. and Phelps, M. E. *Physics in nuclear medicine, 2nd edit.*, 1066

Spencer, M. P. (Ed.). *Cardiac Doppler diagnosis, Vol. II*, 332

Steiner, R. E. and Sherwood, T. (Eds). *Recent advances in radiology and medical imaging (8)*, 142

Stockley, S. M. *A manual of radiographic equipment*, 82

Stoll, B. A. (Ed.). *Breast cancer: treatment and prognosis*, 752

Swallow, R. A., Naylor, E., Roebuck, E. J. and Whitley, A. S. (Eds). *Clark's positioning in radiography, 11th edit.*, 552

Swartz, J. D. *Imaging of the temporal bone: a text/atlas*, 1010

Swischuk, L. E. and Sapire, D. W. *Basic imaging in congenital heart disease, 3rd edit.*, 700

Tabár, L. and Dean, P. B. *Teaching atlas of mammography, 2nd revised edit.*, 996

Taveras, J. M. and Ferruci, J. T. (Eds). *Radiology. Diagnosis — Imaging — Intervention*, 590

Thijn, C. J. P. *Radiology of the hand: a diagnostic synopsis of many general diseases*, 122

van Breda, A. and Katzen, B. T. *Digital subtraction angiography: practical aspects*, 428

van Rijk, P. P. (Ed.). *Nuclear techniques in diagnostic medicine*, 524

Vaeth, J. M. and Meyer, J. (Eds). *Treatment planning in the radiation therapy of cancer*, 1098

Vogler III, J. B., Helms, C. A. and Callen, P. W. (Eds). *Normal variants and pitfalls in imaging*, 534

Voûte, P. A., Barrett, A., Bloom, H. J. G. and Lemerle, I. *Cancer in children. Clinical management. 2nd edit.*, 752

Wackenheim, A. *Cervico-occipital joint*, 198

Wagner, H. N., Buchanan, J. W. and Espinola-Vassallo, D. *Diagnostic nuclear medicine: patient studies*, 1066

Wall, B. F., Hillier, M. C. and Kendall, G. M. *An update on the frequency of medical and dental X-ray examinations in Great Britain — 1983. NRPB R201*, 1118

Weiss, H. and Weiss, A. *Ultrasound atlas: a real-time ultrasound imaging in internal medicine*, 1034

Weissman, A., Clot, M. and Grellet, J. *Double contrast examination of the colon (principles and practice)*, 206

Wicke, L. *Atlas of radiologic anatomy, 4th edit.*, 1034

Williams, A. T. *Essentials of orthopaedic surgery*, 198

Williamson, B. D. P., Le Heron, J. C., Poletti, J. L. and Cartwright, P. H. *A glossary of physics, radiation protection and dosimetry in diagnostic organ imaging*, 914

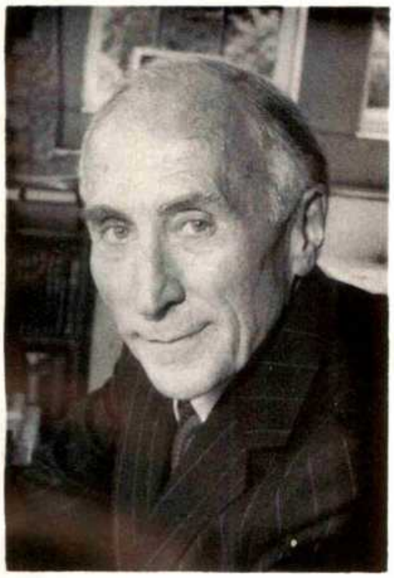
Winkler, C. (Ed.). *Nuclear medicine in clinical oncology. Current status and future aspects*, 872

Zülch, K. J. *Brain tumours. Their biology and pathology, 3rd edit.*, 1010

BIR Bulletin

December 1987

Obituary



Dr N. A. Lewtas, MB, ChB, FRCP, FRCR, DMRD

It was with very deep sadness that the medical community of Sheffield learnt of the death of their dear friend and colleague, Norman Lewtas, who passed away on September 12, 1987, after a short illness.

It was my privilege and pleasure to have been a consultant radiological colleague of Norman from 1959 until his retirement in 1982. Throughout those years I cannot recall any ill-feeling or tension between Norman and his clinical or radiological colleagues. He was always relaxed, thoughtful and a pleasure to work with.

Norman was born and educated in Manchester, and qualified from its Medical School in 1941. The remainder of the war years he spent in the Royal Army Medical Corps, serving in Europe, India and the Sudan, and being mentioned in dispatches. After the war he returned to Manchester, and following several medical appointments commenced his radiological training in 1950. He was appointed consultant radiologist to the United Sheffield Hospitals in 1955. He was a superb neuroradiologist with a wealth of technical and interpretative experience, always practical and economical in his methods and an eager collaborator in any project developed with his clinical and radiological colleagues. He was a tremendous worker, carrying the major responsibility for nearly 30 years for the huge neuroradiological workload generated by over two million people in the North Trent region.

His skills and experience were very highly regarded throughout the country and he was a regular attender and contributor to regional and national neuroradiology organisations. Norman was an excellent teacher of both neurological and general radiology, especially on a one-to-one basis, and many radiologists throughout the country learned their art and skills from him in Sheffield. He followed the late John Wilkie as administrative head of the Department of Radiology at Sheffield Royal Infirmary in 1959, continuing the relaxed leadership of his predecessor and enjoying the total loyalty and devotion of his colleagues, medical, technical and clerical, within that very happy department (big on service, small on space).

Norman was a very kind person, compassionate, understanding, caring, always willing to listen and offer advice to the departmental team who admired and respected him so much. Always elegant, he was deeply respected throughout the hospitals at which he worked, for his charm, sincerity, dedication, sound advice and commonsense practical approach to all problems, be they medical, administrative or social. By nature a fast mover, whether in technical procedures, walking or driving his favourite "souped-up" Escort, Norman always found time and gave his full attention and consideration to anyone seeking his advice, help and wisdom.

At his funeral, the lovely old church at Eyam was crowded with his family, colleagues and friends, who travelled from far and wide to pay their respects, and to hear the vicar's most moving, personal and very perceptive word-picture of Norman, the man. His very many friends offer their deepest sympathy to his wife Dorothy and to their two children.

Norman was both a gentleman and a gentle man, who with great sensitivity and humility was totally dedicated to his family, patients and colleagues. We in Sheffield are privileged to have known and worked with him.

R. G. Grainger

Historical Working Party

An interdisciplinary and transinstitutional working party was founded at a meeting at the British Institute of Radiology, 36 Portland Place, on Friday, September 11, 1987. The meeting was chaired by Professor Ian Isherwood and was attended by several individuals pursuing an active interest in the history of medical radiology and radiography. The following institutional groups were represented: The British Institute of Radiology, The College of Radiographers, The Institute of Physics in Medicine, The Royal College of Radiologists, and The Section of Radiology of The Royal Society of Medicine. Invited but unable to attend were representatives of the Wellcome Museum for the History of Medicine, the Contemporary Medical Archives Centre of the Wellcome Institute, and the Wellcome Unit for the History of Medicine and Science of the University of Manchester. The agreed terms of reference of the group are:

1. To co-ordinate activities in connection with Röntgen's centenary in 1995–1996.
2. To determine ways and means of establishing a database of archival material and matters of historical interest concerned with the development of medical radiology in the British Isles.

The representative members were aked to confer with their parent bodies about possible plans for the centenary. A further report of the working party's activities will be produced following this period of consultation.

Jean M. Guy
Secretary

Statement from the 1987 Washington meeting of the ICRP

The International Commission on Radiological Protection wishes to draw attention to the following extracts from ICRP Publication 48, *The Metabolism of Plutonium and Related Elements* (ICRP, 1986).

Absorption from the gastrointestinal tract

The greatly expanded body of data on the absorption of plutonium from the gastrointestinal tract indicates that absorption is influenced by the mass ingested, by fasting, by incorporation into foodstuffs, by complexing anions, such as citrate and DTPA, and by a variety of other factors. The animal data for the absorption of what appears to be the same compound often show wide fluctuations, which suggests that the absorption may be critically dependent on the chemical microenvironment at the site of absorption.

On the basis of the extensive data presented and discussed in chapter IV of ICRP Publication 48, the fractional absorption (f_1) values listed in Table I are regarded as best estimates for the purposes of radiation protection. It must be emphasised that the proposed value of f_1 of 10^{-3} for unknown or mixed compounds of plutonium and other actinides is considered to provide an adequate margin of safety for radiation protection purposes. For comparison, the f_1 values used in the assessment of the ALIs for workers given in ICRP Publication 30 (ICRP, 1979) are listed in the right-hand column of Table I.

The use of the cautious value of 10^{-3} may not be considered appropriate in all situations where a best estimate of absorption is required, either for a critical group or in estimating population doses. In such cases, if a different value more suitable to the specific situation can be justified, it should be employed.

There is strong evidence to suggest that plutonium absorption from the gastrointestinal tract may be increased by at least an order of magnitude in the human neonate. This increased absorption appears likely to decrease very rapidly during the first days or weeks of life, but the age by which the gastrointestinal absorption of plutonium will have decreased to adult levels is not known. For the first year of life, a value for f_1 of 10^{-2} is suggested, with the adult value of 10^{-3} being applied to all succeeding years. For the assessment of lifetime risk, an f_1 value of 10^{-3}, if applied to general populations, would seem adequately protective for all ages. Much more information on the absorption of actinides and other heavy metals from the neonatal gastrointestinal tract of animals and man is needed.

Retention in liver, bone and gonads

The more recent data from analyses of human tissues for plutonium confirm the previous assumptions that liver and bone are the principal deposition sites and account for about 80% of the plutonium which reaches the blood stream. For reasons that are not understood, the partition of plutonium between liver and skeleton varies widely in individual cases, but the most likely

TABLE I

Comparison of proposed values for f_1 and those recommended in ICRP Publication 30

Element	Type of exposure, compound	$f_1 \times 10^4$	
		This report	ICRP Publication 30
Pu	Occupational exposure		
	oxides, excluding "polydisperse" oxides	0.1	0.1
	nitrates	1	1
	other compounds or unknown mixtures	10	1
	Population exposure (via food chains), all compounds	10	
Np	Occupational and population exposure, all compounds	10	100
Am, Cm, Cf	Occupational and population exposure, all compounds	10	5

average deposition is considered to be 50% in the skeleton and 30% in liver. The available data suggest that this distribution also applies to americium and curium. However, the variability of the deposition of plutonium, americium and curium between individuals is such that, for radiation protection purposes, the ICRP Publication 30 model of equal distribution between skeleton and liver (45% in each) remains an adequate assumption. Animal data indicate that for the actinides of higher atomic number, *i.e.* californium, berkelium and einsteinium, an initial distribution of 65% in skeleton and 25% in liver would seem more appropriate; for neptunium the corresponding values would be 75% and 15%.

The partition of actinides between skeleton and liver in children and neonates is likely to be different from that observed in adults because of the differences in metabolism.

For the gonads, the currently assumed values of 0.035% in testes and 0.011% in ovaries give an unjustified impression of precision, but seem otherwise to be appropriate. However, these figures should be kept under review as more sensitive analytical methods become available for the analysis of human autopsy material.

With regard to the retention parameters, there is considerable evidence to suggest that both the 40-year half-time for plutonium in liver and the 100-year half-time for plutonium in the skeleton, recommended in ICRP Publication 19 (ICRP, 1972) and employed in ICRP Publication 30 are too long. Values of 20 and 50 years for retention half-times in liver and skeleton respectively now seem more reasonable. A case can be made for a shorter retention half-time for americium than for plutonium in liver, but human data are limited and a confident basis for extrapolation of animal data is lacking. At present, no compelling argument can be made for assuming retention times for neptunium, americium or the higher actinides which are substantially different from those of plutonium.

Do *you* have something to say in the *Bulletin*?

Any item likely to be of interest to *Bulletin* readers (preferably brief) would be welcomed from BIR members. Please send material to: The Bulletin Editor, BIR, 36 Portland Place, London W1N 4AT. (Tel. 01-580-4189).

The assumption in ICRP Publication 30 of an infinite retention half-time for all actinides in testes and ovaries is a cautious one, consistent with many of the experimental animal data, although studies in non-human primates suggest a relatively short half-time.

Effect of the proposed changes in f_1 *and retention half-life in liver and bone on ALIs*

The suggested changes in the metabolic parameters have some implications for the values of ALI given in ICRP Publication 30. For isotopes of plutonium of long physical half-life, the ALI for the ingestion of unknown or mixed compounds will need to be decreased by a factor of almost 10. However, the ALIs for ingestion of long-lived isotopes of plutonium as nitrates or oxides, as well as those for the ingestion of isotopes of short physical half-life, where the dose to the intestinal mucosa is of overriding importance, will need little change. Similarly, the effect on ALIs for inhaled isotopes of plutonium will also be small, since, in this situation, transfer from gastrointestinal tract to blood is very small in comparison with transfer from lung to blood. Values of ALI for ingested americium, curium and californium will be much less affected, since the proposed change in f_1 values is only a factor of two. For ^{237}Np, the ALI by ingestion will need to be increased by about an order of magnitude.

The Commission now recommends the adoption of the values and procedures proposed in ICRP Publication 48.

REFERENCES

ICRP, 1972. *The Metabolism of Compounds of Plutonium and Other Actinides.* ICRP Publication 19. A report prepared by a Task Group of Committee 2 of the International Commission on Radiological Protection (Pergamon Press, Oxford).

ICRP, 1979. Limits for intakes of radionuclides by workers. ICRP Publication 30, Part 1. In *Annals of the ICRP, 2,* No. 3/4 (Pergamon Press, Oxford).

ICRP, 1986. The metabolism of plutonium and related elements. ICRP Publication 48. In *Annals of the ICRP, 16,* No. 2/3 (Pergamon Press, Oxford).

Radiation standards and the ICRP meeting on September 8, 1987

The following letter was received from Friends of the Earth too late to be published before the ICRP meeting in Como. The views expressed in the letter are strictly those of Friends of the Earth, and we publish it solely for the information of members of the Institute.

On September 8, 1987, the International Commission for Radiological Protection (ICRP) meets in Como, Italy. This will be an important meeting for a range of reasons. Since 1950, the ICRP have provided advice and made recommendations on radiological protection. These recommendations provide the basis for both national and international radiation safety standards for both workers and members of the public. The Como meeting is likely to see a revision upwards in the risk estimates for low-level radiation, at least by a factor of two if not a factor of five. This will be the first time that new data from Hiroshima and Nagasaki have been considered by the ICRP. Other data relating to studies of a number of occupational groups will also be considered. Decisions taken at the Como meeting are likely to set the new radiation standards for the next 10–15 years.

In view of the significance of the meeting, Friends of the Earth (UK) have produced a briefing pack in order to explain the need for at least a fivefold increase in radiation risk estimates, and to provide details on the past and present membership of the ICRP. We will be presenting evidence to ICRP and hope to be allowed to do this orally. We are also co-ordinating an international scientists' declaration to the ICRP, calling for changes in the risk estimates, and the recommended dose limits. Hitherto, most of the operations of the ICRP have been conducted in secret and have not been open to public scrutiny. One of the purposes of the briefing is to widen the debate about radiation safety in view of the wide public concern on this issue.

Copies of the briefing and the declaration are available from: Energy Campaign, Friends of the Earth, 377 City Road, London EC1V 1NA.

STEWART BOYLE
National Energy Campaigner, FoE (UK)

A report of the ICRP meeting in Como will be published in a forthcoming issue of the *Bulletin.*

Press releases

WHO/ISR sponsored training centre, Kenya: appeal for support and contributions

Analysis of the present global situation of radiological services shows a great discrepancy throughout the world between the developing and the industrialised countries. More than three quarters of the world population is at present covered by radiological services at an unsatisfactory level. A major constraint is the poor technical performance of X-ray machines, which were not specially designed for difficult conditions such as adverse climate.

To cover the basic needs of manpower for radiologic services, there is obviously a lack of training centres geared to provide systematic guidance, instruction and experience for radiologists and radiographers in training. The training and experience received in Western countries is often irrelevant and out of the context of the requirements of the home country. For this reason it is better to provide training in a home environment.

The International Society of Radiology (ISR), in co-operation with the World Health Organisation (WHO), is currently establishing a radiological training centre for the English-speaking countries in Africa at the Department of Radiology, Kenyatta Hospital, University of Nairobi, Kenya. The WHO has provided funds to build teaching facilities with lecture/seminar rooms, library, teaching file space, audiovisual room and faculty offices.

The training programme, of 3 years' duration commencing in October 1985, includes two residents from Tanzania, one from Uganda and four from Kenya. In October 1986 the intake consisted of five residents, one from Lesotho, one from Tanzania, one from Uganda and two from Kenya.

To ensure the continuous financial and scientific support of this teaching centre, the ISR would be very grateful for support in this important venture for the promotion of radiology on the African continent. The most essential contributions are the delegation and financing of visiting professors for a minimum duration of 1 month and the donation of teaching material, such as annotated teaching films, books, journals and videotapes.

For further information, please contact either the General Secretary of the ISR, W. A. Fuchs, MD, or the Chairman of the International Commission on Education of the ISR, P. Cockshott, MD, McMaster University, Department of Radiology, 1200 Main Street West, Hamilton, Ontario, Canada L8N 3Z5.

New Philips ultrasound system optimizes image quality, versatility

The new SDR 1550XP real-time ultrasound system is designed for virtually any sector or linear imaging application. Another major factor in improved linear image quality is the addition of a fourth focal zone, which sharpens focus in the near field. The new Philips system offers a full range of transducers, including 3 and 5 MHz general-purpose sector, 5 MHz neonatal, 7.5 MHz small parts, 5 MHz endovaginal and 4 and 6 MHz linear array.

In addition to the extensive calculations package found in the SDR 1550, the SDR 1550XP includes hip quantification, which provides automatic neonatal hip dysplasia calculations that are quick and accurate. The compact new system weighs only 67 pounds (30.5 kg) which makes it easily movable to any location. The SDR 1550XP is compatible with the Philips SDD 600 duplex Doppler system.

Further information is available from Mr A. E. Lattimore, Kelvin House, 63/75 Glenthorne Road, London W6 0LJ (Tel. 01-741-1666).

Varian and IBM agree on patent licensing

Varian Associates, Inc. announced that it has reached an agreement with IBM which allows each company use of the other's patents in their respective fields of interest.

The arrangement, known as a cross licensing agreement, is limited to an exchange of patent licensing rights in the companies' current business areas. The agreement provides Varian with access to a broad range of patented technology, including developments in such areas as superconductivity and factory automation in device fabrication, which may provide beneficial in its communications, analytical instrument, and medical and semiconductor equipment operations. Likewise, for example, IBM will have access to Varian's patented semiconductor manufacturing technology for use in its internal chip manufacturing processes.

Fetal weight program now included in Imex real-time scanner

The Daisy linear/sector scanner fro Imex now includes a built-in estimat fetal weight program. This program just one of five gestational age table activated with a single comput keystroke. Also included are BP crown–rump length, head ar abdominal circumference and femu length tables. All tables are also use programmable if preferred. Circumference can be calculated from just tw diameters. The high resolution dua linear display simplifies comparison including BPD on one side and abdominal circumference measurements on the other. Joystick-controlle double dual calipers, an exclusive Dais feature, enable simultaneous measurements of both images. A new autofilm camera produces instant Polaroid images that eliminate timing or peeling of the film. Photographs have better resolution than conventional Polaroid prints.

Instillagel

CliniMed has now taken over the U agency for Instillagel, a sterile, antiseptic, anaesthetic, lubricant gel in a pre-loaded disposable syringe. Instillagel is designed for convenient use during catheterisation and is available on NHS prescription. The gel contains 2% lignocaine hydrochlorid BP, and 0.25% chlorhexidine gluconat solution BP, whose spectrum of anti microbial activity has been broadene by the addition of methyl hydroxy benzoate and propyl hydroxybenzoate.

The syringes are available in two sizes, 6 ml and 11 ml. Both syringes are especially designed for intraurethral administration and have an integral nozzle carefully shaped for atraumatic instillation. The 11 ml syringe contain enough gel to lubricate the male urethr along its whole length, while the 6 ml syringe is more suitable for paediatric and female use. The viscosity of the gel is such that the syringe is easy to squeeze when the gel is being instilled. Instillagel is also useful in cystoscopy where the optical clarity of the gel is vital. The sterile, clear blister pack is well suited for use in the operatin theatre.

For further information, pleas tact: CliniMed Limited, Cavell Amersham Hill, High Wycombe, HP13 6NZ. Tel. 0494 444027.

IR calendar vents

nless otherwise indicated, enquiries out the following events should be ddressed to the Conference Manager, ritish Institute of Radiology, 36 rtland Place, London W1N 4AT (Tel. -580 4085).

The meetings are at 36 Portland Place nless otherwise stated. Attendance is pen to non-members.

Chemical Modification of Radiation Effects: Experimental and Clinical
November 13, 1987 at 11.00 a.m.
All-day radiobiology work-in-progress meeting.

New Radiopharmaceuticals and Their Clinical Application
November 27, 1987 at 10.00 a.m.
Scientific Societies, London W1
Organised by the Nuclear Medicine Subcommittee.
Speakers: Dr K. E. Britton, Dr I. Brown, r D. Le Bars, Dr P. J. Ell, Dr B. ngström, Dr M. C. Lasne, Dr N. A. assen, Dr S. K. Luthra, Dr H. J. Machulla, Dr M. V. Merrick, Dr A. D. Nunn, Dr P. F. Sharp, Dr A. M. Verbruggen and Dr G. D. Zanelli.

Lasers—Applications in Radiology
January 14, 1988 at 5.30 p.m.
Joint BIR/RCR/RSM meeting.
hairman: Dr W. D. Jeans.
peakers: Dr A. L. Mackenzie, Dr D. C. umberland, Dr S. G. Bown, Mr D. othery, Dr G. Watson and Dr S. Hart.

Clinical Usefulness of Nuclear Medicine Image Processing
February 9, 1988
Joint IPSM/BIR meeting organised by the IPSM.
urther details: General Secretary, PSM, 2 Low Ousegate, York YO1 1QU (Tel. 0904-610 821).

Institute Sponsored Visits to Paris

Members should write to the General Secretary of the BIR for application to visit radiotherapy centres in Paris, arranged through the boration of Professor M. ana.

Functional Insights From Magnetic Resonance
February 17, 1988
University College and Middlesex School of Medicine, London, W1
Organised by the Diagnostic Methods Committee.
Chairman: Prof. B. S. Worthington
Speakers: Dr M. A. Smith, Mr D. Longmore, Dr I. Young, Dr D. Hadley, Prof. I. Isherwood, Dr S. Williams, Prof. R. H. T. Edwards, Prof. O. Reynolds, Dr J. Cox and Dr V. R. McReady.

This meeting will incorporate the 1988 **Silvanus Thompson Memorial Lecture**, by Prof. P. Mansfield "Structural and functional investigations by real-time echo planar imaging". This lecture will be open to non-registrants.

Radiobiology All-Day Non-topic Proffered Papers Meeting
February 19, 1988
Organised by the Radiobiology Subcommittee.

Too Much Radiation in Radiodiagnosis?
March 9, 1988
University College and Middlesex School of Medicine, London W1.
All-day meeting organised by the Industry and Radiation Protection Committees.
Chairman: Dr J. G. Russell.

Total-Body Irradiation
April 13, 1988
Joint BIR/IPSM meeting organised by the BIR.

Conversazione
June 23, 1988
Institute of Directors, London SW1
Lecture by Sir George Pollock

Curt Westman Scholarship
The new owner of the late Dr Westman's Clinic in Vällingby, Sweden—AB Medicinsk Röntgen—will continue to host one BIR sponsored radiologist annually. AB Medicinsk Röntgen will provide one return air fare and 2 weeks' accommodation in Sweden, and may help with contacts should the visitor wish to visit other diagnostic centres in Sweden.

The sponsored visit will be known as the Curt Westman Scholarship in memory of the late Dr Westman who was an Honorary Member of the Institute and helped many young British radiologists who had visited his clinic over the years.

The first recipient of the Curt Westman Scholarship is Dr Caroline Boggis, a senior registrar from Manchester, and a report of her visit will be published in the *Bulletin* in the new year.

Members should write to the General Secretary for further information on the Curt Westman Scholarship. Applications for 1988 will close on January 14, 1988.

RADIOLOGY '88

GLASGOW

23-25 May 1988

The 46th Annual Congress of the *British Institute of Radiology* incorporating the joint Spring Provincial meeting and in collaboration with the Scottish Radiological Society. To be held at the Scottish Exhibition and Conference Centre, Glasgow.

Radiology '88 will be the first in a series of joint ventures with the College of Radiographers. The two complementary though separately organised conferences will be spanned by a joint technical exhibition, MED **X** RAY, which will be Britain's largest radiological technical exhibition.

Radiology '88 will cover the breadth and depth of modern radiology, both diagnostic and therapeutic.

Advance programme and registration forms are available now from the Conference Office. Registration fees have been held at 1987 rates but will increase on January 31, 1988 so book early to save money!

Library news

The BIR Library is open weekdays 9 a.m.–5 p.m. (7 p.m. on Thursdays)

The Librarian, Mrs Gunnel Ingham, is in attendance Tuesdays 11 a.m.–5 p.m., and Thursdays 11 a.m.–7 p.m., and Mrs Angela Lansdown, daily 9 a.m.–5 p.m. (Tel. 01-580 4085).

The journal stock includes more than 100 titles. Though journals may not be taken out of the library, there is a photocopy service, also available by post. A list of current journals is available on request and is also published in the March and September issues of the Bulletin. *Most books (excepting the historical collection) are available on loan.*

There is an agreement which allows BIR members limited use of the RSM Library for reference purposes. Members should apply to the BIR Librarian for a visitor's card.

Recent additions to the Library

Grainger, R. G. & Allison, D. J. (Eds). Diagnostic radiology. Anglo-American textbook of imaging. Vols 1–3. 1986

Voûte, P. A. et al (Eds). Cancer in children: clinical management. 2nd edit. 1986

National Cancer Institute. NCI Monographs, No. 4. First conference on DNA topoisomerases in cancer chemotherapy. 1987

Meetings and courses

As a service to our readers, the title, date and place of meetings and contact address will be inserted free of charge: any additional information will be charged at £1.75 per printed line, per insertion. Please contact the Managing Editor.

Nuclear Medicine—Biannual Intensive Course
January 29–30, 1988
UMDS St Thomas's Hospital Medical School Postgraduate Centre, London
Further details: Miss Erica Mendy, Postgraduate Secretary, St Thomas's Hospital, Lambeth Palace Road, London SE1 7EH. Tel: 01-928 9292 ext 2072.

The Management of Malignant Diseases of the Central Nervous System and Eye in Childhood
February 18–19, 1988
Hospital for Sick Children, Great Ormond Street, London
Further details: Brenda Clayden, The Institute for Child Health, Guildford Street, London WC1. Tel: 01-829 8692.

Screening and Management of Breast Cancer
March 11, 1988
St Bartholomew's Hospital
Further details: Miss T. Cocks, Department of Radiotherapy, St Bartholomew's Hospital, London EC1. Tel: 01-601 8351.

In Vivo Diagnosis and Therapy of Human Tumours with Monoclonal Antibodies
March 16–19, 1988
Naples
Further details: Idelson s.n.c., Via A. De Gasperi, 55, 80133 Napoli, Italy. Tel: 0039-81-324733/320741.

6th International Meeting on Chemical Modifiers of Cancer Treatment
March 21–25, 1988
Paris, France
Further details: Dr E. P. Malaise, Laboratoire de Radiobiologie Cellulaire (Unité Inserm 247), Institut Gustave-Roussy, 94805 Villejuif Cedex, France

Radiation Research Society, 36th Annual Meeting
North American Hyperthermia Group, 8th Annual Meeting
April 16–21, 1988
Philadelphia, Pennsylvania
Further details: Radiation Research Society, 1101 Market Street, 14th Floor, Philadelphia, PA 19107, USA. Tel: 215-574-3153.

Fifth International Symposium on the Planning of Radiological Departments
April 20–23, 1988
Florence, Italy
Further details: ISPRAD V Organizing Secretariat, CLAS Editoriale, Via Pace 8, 25122 Brescia, Italy.

Radiology Review Course
May 1–6, 1988
Miami, Florida, USA
Further details: Carol Lamarre, Program Coordinator, University of Miami School of Medicine, Department o Radiology, (R-109), PO Box 016960 Miami, Florida 33101, USA. Tel: 305 549-6894.

3rd International Symposium on Neutron Capture Therapy
May 31–June 3, 1988
Bremen, FR Germany
Further details: Prof. Dr D. Gabel, Dept of Chemistry, University of Bremen, Box 330 440, D-2800 Bremen 33, FR Germany

Cardiovascular and Interventional Radiological Society of Europe and the American Society of Cardiovascular and Interventional Radiology
June 12–17, 1988
Berlin
Further details: Reingard Sörensen, MD, Klinikum Steglitz, Röntgendiagnostik Hindenburgdamm 30, D-1000 Berli 45, West Germany.

4th International Copenhagen Symposium on Detection of Breast Cancer
August 24–26, 1988
Gentofte Hospital, University of Copenhagen
Further details: Dr med. S. Brünne KAS Gentofte, Roentgenafdelingen DK-2900 Hellerup, Denmark.

Symposium on Computed Tomography and Magnetic Resonance in Medicine
October 17–18, 1988
25th Congress of Radiology
October 18–20, 1988
Berlin, DDR
Further details: Dr W. Angerstein, Institut für Röntgendiagnostik, Charite, Schumannstr. 20/21, DDR-1040 Berlin.

Workshop: Progress in Regional Cancer Therapy
November 3–5, 1988
Vienna, Austria
Further details: c/o B. Schick, Abteilung für Experimentelle, Chirurgie der I. Chirurgischen Universitätsklinik, Alser Strasse 4, A-1090 Vienna, Austria (Tel 0222-4800/2301).

Training Fellowships

1988-89

The Medical Research Council's Training Fellowship scheme enables **medical and dental graduates** at any stage in their career up to and including Senior Registrar, Lecturer or equivalent levels, and **science graduates** with research experience to gain specialised **research training** in the biomedical field in the UK.

Applications are now invited from suitably qualified candidates for awards to be taken up in the 1988-89 academic year. Fellowships may be held for periods of from six months to three years.

The Council would particularly welcome applications within the fields of AIDS (including tetrovirology), biochemistry of parasites, calcium metabolism, epidemiology, Health Services research, infections (including viral disease), magnetic resonance imaging, neuropathology, pathology, and radiotherapy.

QUALIFICATIONS: **Graduates in medicine and dentistry:** from post-registration up to Senior Registrar or equivalent academic levels. **Graduates in science** PhD/DPhil (or in certain circumstances MSc plus at least 3 additional years' postgraduate experience).

TRAINING PROGRAMMES: proposals may be submitted for specialised research training or in the case of medical/dental graduates for training in a basic subject relevant to a particular clinical interest. Fellowships are also available to provide support for medical/dental graduates wishing to attend one-year research-orientated courses leading to an MSc.

EMOLUMENTS: appropriate point, with increments, on the current NHS or university lecturer scales.

MRC

Medical Research Council

For further details and an application form, write to Medical Research Council, Training Awards Group, 20 Park Crescent, London W1N 4AL.

Closing date for receipt of applications: 1st February 1988. Late applications will not be accepted.

LECTURE and MEETING FACILITIES

Available for hire
36 Portland Place, W1

Fully equipped air conditioned Lecture Theatre with seating capacity for 100 people.
Very attractive Library with Adam decor available for functions, buffets etc., capacity approximately 100.

For list of charges please apply to the General Secretary, British Institute of Radiology, 36 Portland Place, London W1N 4AT or telephone 01-580 4085

Reprinted from *British Journal of Radiology*, 1983, *56*, 147–170

Review article: The radiological effects of nuclear war

Report of a BIR Working Party
(Chairman: Professor J. S. Boag)

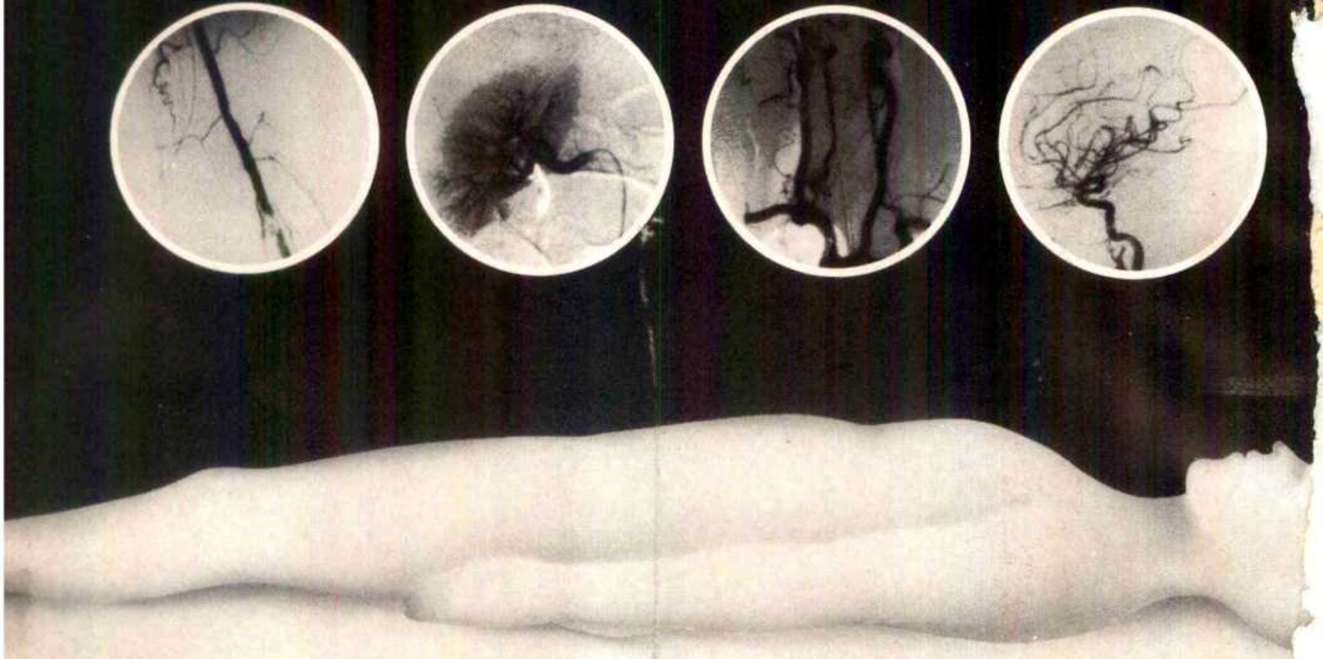
Reprints, price £1.95 each, available from:

The British Institute of Radiology
(Publications)
36 Portland Place
London W1N 4AT
Tel: 01-580 4085

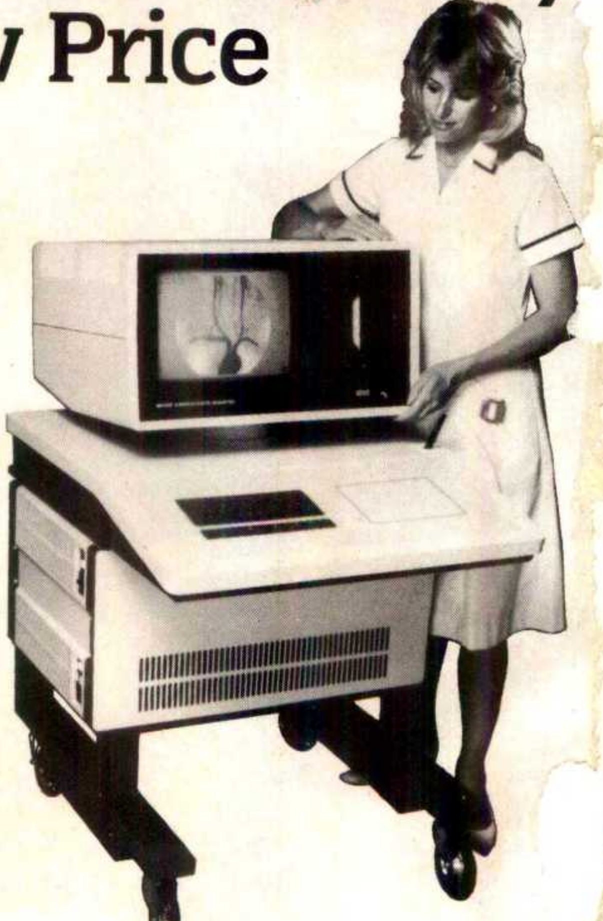
(*Remittance with order please*)

British Made

Digital Subtraction Angiography



Outstanding Picture Quality at a Low Price



Quantel's totally new concepts in video processing, developed over 15 years for the TV world, make IDIS a truly revolutionary product. Previously time consuming and complicated angiography tasks can now be performed in seconds — and you don't have to be a computer programmer to operate IDIS. As the development costs were borne by the broadcast industry the price for IDIS is surprisingly attractive.

IDIS is easy to install too. All you need is a simple coaxial cable connected to the fluoroscopic output of your system. No air conditioning or special power is needed, just plug it in to a standard domestic socket and IDIS is ready for action. Use of high density multi-layered printed circuits result in a small compact unit — easily wheeled from room to room.

For the technically minded, IDIS uses — Analogue/Digital converters to digitise signals at 10 million samples per sec; Recursive Video Processor for real-time noise reduction; State-of-the-art 32 bit microprocessors for fast digital calculation; 168 Mbyte Winchester disks for vast picture library; new technology 10 Mbyte removable floppy disk cartridges. Features such as Matched Temporal Filtering, Spatial Filtering, Interpolated Zoom and Dynamic Contrast Adjustment give startling picture clarity and versatility to optimise accurate diagnosis.

IDIS leads the field in DSA and is backed by Quantel's world acclaimed service.

– for innovative medical imaging

IDIS

QUANTEL, 31, Turnpike Road, Newbury, Berkshire RG13 2NE. Tel: (0635) 322

(continued from outside back cover)

Page

Correspondence

Barium embolisation during barium enema examination 1236
M. D. Lewars

Reply 1236
S. Fowlie, J. R. Barton and G. M. Fraser

Breast screening in China 1237
A. E. Hugh

Translumbar aortography 1237
H.-J. Maurer

Reply 1238
W. D. Jeans

Modification of the Selectron standard applicator for gynaecological treatment 1238
J. Cygler, B. Lavigne and G. P. Raaphorst

A quarter of a century ago 1239
J. T. Patton and N. J. McNally

Index to volume 60 *follows text*

Book reviews

Radiation oncology, Vol. 2. *T. L. Phillips and W. Wara* (Eds) 1196
Care of the cancer patient, 2nd edit. *L. G. Capra* 1196
Computed tomography of the gastrointestinal tract. *A. J. Megibow and E. J. Balthazar* (Eds) 1210
Atlas of ultrasonographic artifacts and variants. *R. C. Sanders* 1210
Plain X-ray diagnosis of the acute abdomen. *M. H. Gough, M. W. L. Gear and A. S. Daar* 1220
Neurosonography of the pre-term neonate. *E. G. Grant* (Ed.) 1230
Ultrasound in perinatology. *N. F. Maklad* (Ed.) 1230

BIR Bulletin and Calendar events *follows index*

Featured in the next issue

Adverse reactions during intravenous urography: are these due to histamine release?
C. M. Herd, A. R. Robertson, D. B. Frewin and W. B. Taylor

In-vivo measurement of spin lattice relaxation time of bone marrow in healthy volunteers
M. A. Richards, J. A. W. Webb, S. E. Jewell, W. M. Gregory and R. H. Reznek

Costing imaging procedures
P. M. Bretland

Technical note: Extending the range of sensitivity for detecting DNA strand breaks
P. L. Olive, A. P. S. Chan, C. S. Cu and S. H. Macphail

Revised instructions to authors

VOL 60 NO 720 DECEMBER 1987

The British Journal of Radiology

Contents

Page

The Chernobyl reactor accident: the impact on the United Kingdom (1987 Mayneord Lecture) 1147
F. A. Fry

Nuclear reactor accidents: preparedness and medical consequences

Medical and radiobiological basis of radiation accident management 1159
C. C. Lushbaugh, S. A. Fry and R. C. Ricks

Medical basis for the establishment of intervention levels 1163
J. C. Nénot

Experience of a specialised centre in the organisation of medical care of persons exposed during a nuclear reactor accident 1169
N. M. Nadezhina

The role of NHS hospitals in the preparedness for nuclear accidents 1171
P. J. Bourdillon

United Kingdom nuclear reactor design and operation 1174
B. Edmondson

Emergency planning 1177
J. K. Wright

Nuclear emergencies: medical preparedness 1180
R. A. F. Cox

Reactor accidents in perspective 1182
R. H. Clarke

Regression of the radiological changes of Gaucher's disease following bone marrow transplantation 1189
F. Starer, J. D. Sargent and J. R. Hobbs

Computed tomographic myelography in the investigation of childhood scoliosis and spinal dysraphism 1197
C. I. Rothwell, W. St C. Forbes and S. C. Gupta

Quantitative assessment of lung damage due to bleomycin using computed tomography 1205
E. A. Bellamy, D. Nicholas and J. E. Husband

Infantile recurrent sialectatic parotitis: the role of sonography and sialography in diagnosis and follow-up 1211
L. Rubaltelli, T. Sponga, F. Candiani, F. Pittarello and M. Andretta

The effect of oral magnesium-containing bowel preparation agents on mucosal coating by barium sulphate suspensions 1215
B. G. Conry, S. Jones and C. I. Bartram

Effect of cirrhosis on accuracy of ^{99}Tc^{m}-tin colloid scintigraphy and ultrasound scanning in diagnosis of hepatocellular carcinoma 1221
P. Powell-Jackson, A. Forbes, M. Michell and R. Williams

Case reports

The association of post-radiation thyroid nodular disease with compensated hypothyroidism 1223
I. Doniach, J. E. Kingston, P. N. Plowman and J. S. Malpas

Skin reaction following aminoglutethimide and radiotherapy 1226
D. S. Williams and M. D. Leslie

An unusual case of haemobilia 1228
W. Dock, F. Grabenwöger, G. Bardach, F. Pinterits, W. Klepetko and G. Laufer

Case of the month

"All's well that ends well" 1231
J. Bell, J. Kabala and M. Horrocks

Short communication

Uptake and additivity of the radiosensitising effects of Ro 03-8799 and SR-2508 in mammalian cells *in vitro* 1233
M. E. Watts, M. F. Dennis and M. Woodcock

(continued on inside back cover)

© 1987: The British Institute of Radiology. This publication is copyright under the Berne Convention and the Universal Copyright Convention. All rights reserved, apart from any relaxations permitted under national copyright laws, no part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means without the prior permission of the copyright owners. Permission is not, however, required to copy abstracts of papers or of articles on condition that a full reference to the source is shown. Multiple copying of the contents of the publication without permission is always illegal. Published by The British Institute of Radiology, 36 Portland Place, London W1N 4AT. Printed in Great Britain by The Whitefriars Press Ltd., Tonbridge. ISSN 0007 1285 18304